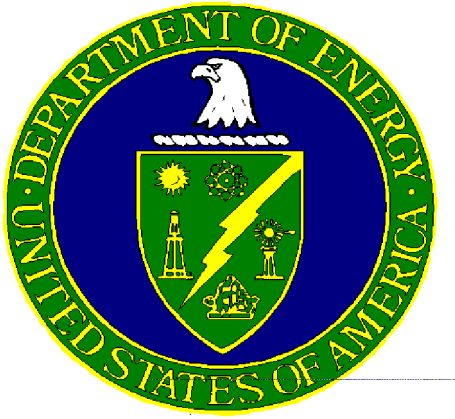
June 1996
Rev. 1

GENERAL TECHNICAL BASE

QUALIFICATION STANDARD

Defense Nuclear Facilities
Program Technical Employees

STUDY GUIDE



Rocky Flats Field Office
Golden, Colorado 80402

Revision 1
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1. PURPOSE

The purpose of this study guide is to provide a single document containing the information required for a Department of Energy (DOE) technical employee to successfully complete the General Technical Base Qualification. In addition to providing the information essential to qualification, references have been included in each section to guide the qualifying employee to additional resources for specific topics.

2. SCOPE

This study guide has been developed to address the competency statements in the May 1995 edition of the DOE General Technical Base, Qualification Standard for Defense Nuclear Facilities Technical Employees. Competency statements and "Supporting Knowledge and/or Skills" statements from the Qualification Standard are shown in bold italics while the corresponding information required to satisfy each statement is provided below it. This study guide is broken down into stand alone sections which correspond to the sections in the qualification standard. It is intended that all DOE employees who are required to complete the General Technical Base Qualification will have access to this document.

A study guide has not been developed for the Technical Communications section of the qualification standard because this section requires personnel to demonstrate communication skills within their organization.

The May 1995 edition of the DOE General Technical Base, Qualification Standard contains numerous competency statements which reference old DOE orders ("four digit orders") which have been superseded by new DOE Orders ("three digit orders"). Every attempt has been made to discuss the DOE Order which is currently in effect as of June 1996. Although this study guide may present information regarding a new DOE Order it should be noted that a superseded order may still be included in an existing contract. The cancellation section in a new DOE order typically contains the following language regarding contractual obligations: "Cancellation of an order does not, by itself, modify or otherwise affect any contractual obligation to comply with such an Order. Canceled orders that are incorporated by reference shall remain in effect until the contract is modified to delete the reference to the requirements in the canceled Orders."

Any questions or comments regarding this study guide should be directed to Don Rack at telephone number 303-966-2024.

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SECTION 1: NUCLEAR PHYSICS FUNDAMENTALS

1.1 Personnel shall demonstrate knowledge of basic atomic structure.

a. Identify the basic particles that compose the atom and describe their relationship, associated mass, and charge.

An atom is composed of three basic particles: protons, neutrons and electrons. Protons have a charge of +1 electronic charge unit (ecu), a rest mass of 1.6725×10^{-27} kg or 1.0073 atomic mass units (amu) and are found in the nucleus (or center) of an atom. Neutrons have no charge, a rest mass of 1.6748×10^{-27} kg or 1.0087 amu and are also found in the nucleus of an atom. Electrons have a charge of -1 ecu, a rest mass of 9.1091×10^{-31} kg or 0.0005 amu (approximately 1/1800 the mass of a proton) and are found in the orbital shells surrounding the nucleus of the atom. (Subsequent research in the area of nuclear physics has revealed that leptons and quarks are the true elementary particles. For example: a neutron consists of two down quarks and one up quark.)[1]

b. Describe the Bohr Model of the atom.

In 1913, Niels Bohr developed a model to describe the make up of a hydrogen atom. He postulated that the atom consisted of a dense nucleus containing a proton and one electron traveling around the nucleus in a discrete circular orbit. Additionally, he postulated that all electron orbits are discrete, the energy change experienced by an electron changing from one allowed orbit to another is quantized (a discrete fixed amount of energy is associated with a change from a specific orbit to another specific orbit) and an electron may not remain between these orbits. Bohr's postulates and his model of the hydrogen atom can be used to understand the make up of all atoms. Atoms consist of a dense nucleus of protons and neutrons which are loosely surrounded by electrons in various discrete orbital shells. The Hydrogen isotope with a nucleus consisting of one proton is the only atomic nucleus without neutrons. Subsequent research has revealed that electrons do not actually orbit the nucleus, but they do behave in accordance with Bohr's postulates and they occupy specific regions with defined shapes and sizes (specified by quantum numbers) around the nucleus which are called orbitals. [1,2]

c. Define the following terms:

Atomic Number - The number of protons in the nucleus of an atom (may also be referred to as nuclear charge). The symbol for atomic number is Z. The

number of protons and the corresponding equal number of electrons in the atom's orbital shells determines the chemical nature of the element. Thus a specific atomic number corresponds to the atom's chemical element symbol. For example: atomic number Z = 6 corresponds to C which is the chemical element symbol for carbon.

Mass Number - The number of protons and neutrons in the nucleus of an atom. The symbol for mass number is A. The particles in the nucleus of an atom (i.e.: protons & neutrons) may also be referred to as nucleons. Because the mass of an electron is very small compared to a proton or neutron the mass number of an atom is essentially the same as the atomic weight Atomic weight is the weight of an atom of a particular element in atomic mass units (amu).

Nuclide - Each type of atom that contains a unique combination of protons and neutrons is called a nuclide. Not all combinations of numbers of protons and neutrons are possible, however approximately 2500 specific nuclides with unique combinations of neutrons and protons have been identified.

Isotope - Atoms or nuclides with the same atomic number (protons) but a different number of neutrons are isotopes of the same element. Isotopes of an element have the same chemical properties but different nuclear properties and mass numbers. Most elements have a few stable isotopes and several unstable radioactive isotopes. [1,2]

d. Referring to the ${}^{A}_{Z}X$ notation for a specific nuclide, determine the number of protons, neutrons and electrons.

In the ${}^{A}_{Z}X$ notation: A represents the mass number (protons + neutrons), Z represents the atomic number (protons), and X represents the chemical symbol for the element. In an electrically neutral atom the number of electrons are equal to the number of protons, therefore the number of electrons is normally equal to Z. If an atom has a different number of electrons and protons then it has an electrical charge which is normally shown by a superscript after the X, such as Cl^{-1} or He^{+2} which indicates the charge of the atom in ecu. (Some texts do not indicate the charge when discussing nuclear reactions, however the charge plays an important role in the biological damage caused by radiation.) Examples of the ${}^{A}_{Z}X$ notation for specific nuclides are shown below:

	A=Protons+ Neutrons	Z=Protons	Electrons= Protons-Charge	Neutrons= A-Z	Element Name
$^{1}_{1}H$	1	1	1	0	Hydrogen
$^{14}_{6}C$	14	6	6	8	Carbon
$^{4}_{2}He^{+2}$	4	2	0	2	Helium *
$^{235}_{92}U$	235	92	92	143	Uranium
$^{239}_{94}Pu$	239	94	94	145	Plutonium
$^{127}_{53}I^{-1}$	127	53	54	74	Iodine

* If produced by a radioactive decay $^{4}_{2}He^{+2}$ is referred to as an alpha particle. [2,3]

1.2 Personnel shall demonstrate knowledge of basic nuclear theory and principles.

a. Describe the three forces that are found within a nucleus.

Gravitational forces, Electrostatic forces and Nuclear forces act within the nucleus of an atom. Gravitational forces as described by Newton in classical physics, exist between all bodies with mass. Gravitational forces tend to attract all nucleons toward each other within a nucleus, however the magnitude of this attractive force is extremely small compared to the electrostatic and nuclear forces within the nucleus. (The protons and neutrons in the nucleus of an atom may also be referred to as nucleons.) Electrostatic forces, as described by Coulomb's Law, exist between charged particles (protons +1) within a nucleus. Protons develop a strong repulsive force between other protons in the same nucleus due to their like charge. If only the electrostatic (repulsive) and the gravitational (attractive) forces within a nucleus are considered, the protons in a nucleus should repel one another and cause the nucleus to disintegrate. However, there is a stronger attractive force between the nucleons that is roughly 100 times stronger than the electrostatic repulsion. A strong attractive Nuclear force exists between all nucleons regardless of charge. The strong nuclear force has a very short range and acts over distances approximately equal to the diameter of a nucleus (10^{-13} cm), is non-central (i.e.: does not follow the inverse square law) and exhibits saturation (i.e.: once a stable structure is achieved, additional nucleons are not strongly held).[1,2] In addition to the strong nuclear force, a weak nuclear force (also known as weak interaction or Fermi interaction) exists. It is a force that is several orders of magnitude weaker than electrostatic interaction and effects all particles equally regardless of mass. Its

effect is to transform all particles into electrons and neutrinos through β decay processes. [1]

b. Define mass defect and binding energy and discuss their relationship.

Mass defect refers to the fact that the sum of the mass of the nucleons and electrons of an atom is greater than the actual mass of the atom which is due to the conversion of mass into binding energy when the nucleus is formed. Thus Mass Defect is defined as the difference between the mass of the atom and the sum of the particles' mass which make up the atom. For example: a helium atom ($^4_2$He) with 2 protons, 2 electrons and 2 neutrons has a mass defect calculated as follows:

Mass of the atom = atomic weight from chart of the nuclides [4]
= 4.00260323 amu

Sum (Σ) of particles' mass (2p + 2n +2e) = (2)(1.00727663) + (2)(1.0086654) + (2)(.000548597)
= 4.03298125 amu

Mass Defect (Δm) = Σ particles' mass - mass of the atom
= 4.03298125 - 4.00260323
= 0.03037802 amu

Binding Energy (BE) is defined as the amount of energy that must be supplied to the nucleus of an atom to completely separate its nucleons. This energy is required to overcome the strong nuclear forces holding the nucleus together and it is equal to the amount of energy associated with converting the mass defect to energy using Einstein's equation $E = mc^2$ {where E = energy in Joules (J), m = mass in kilograms (kg) and c = speed of light = 2.998×10^8 meters/second (m/s)}. Thus $BE = \Delta mc^2$. By substituting 1 amu into Einstein's equation and using the proper unit conversions the relationship between binding energy (in MeV) and mass defect (in amu) can be expressed as [2]:

BE = (Δm)(931.5 MeV / 1 amu) Thus the binding energy for the $^4_2$He atom is:

BE = (0.03037802 amu) (931.5 MeV / 1 amu)
= 28.29713 MeV

c. Describe the following processes, and trace the decay chain for a specified nuclide on the chart of the nuclides.

Alpha Decay - An alpha particle ($^4_2\alpha^{+2}$) contains 2 protons and 2 neutrons and

has a +2 charge. An alpha particle has the same structure as a Helium nucleus and may also be indicated by the symbol $^{4}_{2}He^{+2}$. Alpha decay occurs when an alpha particle is ejected from the nucleus of an atom. The ejection of an alpha particle causes the mass number (A) to decrease by 4 and the atomic number (Z) to decrease by 2 and it leaves the newly created atom with two excess electrons. Thus on a chart of the nuclides an alpha decay is represented by a drop of 2 rows and a move to the left of 2 boxes (see sketch below). The following is an example of an alpha decay: $^{239}_{94}Pu \rightarrow {}^{4}_{2}He^{+2} + {}^{235}_{92}U^{-2}$. Almost all naturally occurring alpha emitters are heavy elements with $Z \geq 83$. The energy released in an alpha decay can be calculated based upon the difference between the mass of the parent nucleus and the mass of the daughter nucleus plus the alpha particle by using the binding energy equation. The majority of the energy (approximately 98%) is transferred to the alpha particle as kinetic energy due to the relative masses of the daughter nucleus and the alpha particle and the conservation of momentum. Most alpha particles are emitted with approximately 5 MeV of energy. A gamma ray may accompany the alpha particle depending upon the parent nuclide and the decay mode [2,5].

Beta-Minus Decay - A Beta-Minus decay is the emission of a negatively charged electron from the nucleus (not the electron orbital shells) of an atom. The Beta minus particle may be represented by any of the following symbols: β^-, $^{0}_{-1}\beta$, e^- or $^{0}_{-1}e$. When a β^- particle is emitted, a neutron within the nucleus is converted to a proton causing the atomic number to increase by one while the mass number remains constant. Thus on a chart of the nuclides a β^- decay is represented by an increase of 1 row and a move to the left of 1 box (see sketch below). β^- decay typically occurs with nuclides located to the right of the stable nuclides on the chart. An antineutrino ($^{0}_{0}\upsilon$‘) is also emitted during a β^- decay, however the antineutrino is sometimes ignored because they do not readily interact with matter and they travel away from the nucleus at the speed of light. [2,5] An example of a Beta-Minus decay is: $^{239}_{93}Np \rightarrow {}^{239}_{94}Pu^{+1} + {}^{0}_{-1}\beta + {}^{0}_{0}\upsilon$‘

Beta-Plus Decay - A Beta-Plus decay is the emission of a positively charged electron (also known as a positron) from the nucleus of an atom. The Beta-Plus particle may be represented by any of the following symbols: β^+, $^{0}_{+1}\beta$, e^+ or $^{0}_{+1}e$. When a β^+ particle is emitted, a proton within the nucleus is converted to a neutron causing the atomic number to decrease by one while the mass number remains constant. Thus on a chart of the nuclides a β^+ decay is represented by a decrease of 1 row and a move to the right of 1 box (see sketch below). β^+ decay typically occurs with nuclides located to the left of the stable nuclides on the chart. A neutrino ($^{0}_{0}\upsilon$) is also emitted during a β^+ decay, however the neutrino is sometimes ignored because they do not readily interact with matter and they travel away from the nucleus at the speed of light. [2,5] An example of a Beta-Plus decay is: $^{13}_{7}N \rightarrow {}^{13}_{6}C^{-1} + {}^{0}_{+1}\beta + {}^{0}_{0}\upsilon$

Electron Capture - Electron Capture (ε) occurs when a nucleus absorbs or captures an electron from one of the inner orbits of the atom and the electron combines with a proton to form a neutron and emit a neutrino. This process occurs in nuclides with an excess number of protons. The electron captured is normally from the innermost orbit (the K shell), thus the process is sometimes called K-capture. Electron capture leaves an inner orbital shell vacant, and when electrons from outer shells (with higher energies) move to fill the vacancy in the lower energy shell, the excess energy is given off by the emission of characteristic x-rays. Electron capture and Beta-Plus decay (positron emission) result in the production of the same daughter product and the same movement on a chart of the nuclides (see sketch below). They exist as competing processes, however for Beta-Plus decay to occur the mass of the parent atom must be greater than the mass of the daughter by at least the mass of two electrons or 1.022 MeV. If this condition is not met then only electron capture can occur.[2,5] An example of electron capture is: $^{103}_{46}Pd + ^{0}_{-1}e \rightarrow ^{103}_{45}Rh + ^{0}_{0}\upsilon$

The relationship of the products of various nuclear processes to the location of the original nuclide on the chart of the nuclides is illustrated below.[1,4] Nuclear reactions discussed in this study guide are shown in bold with shaded backgrounds. (* Neutron Capture is discussed in section 1.2, f. below.)

protons ↑ neutrons→				
			A+3, Z+2 ^{3}He in	A+4, Z+2 $^{4}_{2}\alpha^{+2}$ in
	A, Z+1 **$^{0}_{-1}\beta$ out**	A+1, Z+1 p in	A+2, Z+1 d in	A+3, Z+1 t in
	A-1, Z $^{1}_{0}$n out	**A, Z** **Original Nucleus**	**A+1, Z** **$^{1}_{0}$n in** *	
A-3, Z-1 t out	A-2, Z-1 d out	A-1, Z-1 p out	**A, Z-1** **$^{0}_{+1}\beta$ out or Electron Capture**	
A-4, Z-2 **$^{4}_{2}\alpha^{+2}$ out**	A-3, Z-2 ^{3}He out			

d. Define the following terms:

Radioactivity is a property of some nuclides characterized by the spontaneous emission of particles (Alpha, Beta or Neutron) or electromagnetic radiation (Gamma or X-rays) or both. Gamma rays are photons of electromagnetic energy emitted from the nucleus of an atom which have a very high frequency while X-rays have a slightly lower frequency (approximately 10^{19} Hz) and are emitted from the orbital shell of an atom when an outer electron jumps down to fill a vacancy in an inner electron orbital. Radioactive nuclides decay in a random manner and the precise time at which a nucleus will decay can not be predicted. However the average behavior can be estimated for a specific isotope if a statistically significant number of atoms of the isotope are studied [2,5].

Radioactive Decay Constant - The radioactive decay constant (λ) is the probability that an atom of a specific radioactive isotope will decay per unit time. The units for radioactive decay constant are inverse time such as 1/sec, 1/hr, 1/yr. etc.. For a given number of atoms (N) of a radioactive isotope, the activity (A) is given by the expression: $A = \lambda N$. The activity of a pure radionuclide is dependent upon the radioactive decay constant and the initial activity (A_0) and it decreases exponentially as a function of time according to the expression [1,2]: $A(t) = A_0 e^{-\lambda t}$.

Curie - A curie (Ci) is unit of measure used to describe the activity (A) or spontaneous disintegration of atoms in a specimen and is defined as 3.7×10^{10} disintegrations per second. This quantity was defined as 1 Curie because it is the activity of 1 gram of $^{226}_{88}Ra$, the isotope which Marie and Pierre Curie isolated and studied in 1898. In SI units, activity is expressed in Becquerels (Bq) and 1 Bq has been defined as 1 disintegration per second.
Thus 1 Ci = 3.7×10^{10} Bq. [1,2,5]

Radioactive Half Life - The radioactive half life of a specific isotope is the amount of time required for half of the atoms of the isotope to undergo radioactive decay. After half of the atoms have decayed the activity will also be half of the original activity. If the radioactive decay constant is known, the half life can be calculated since:

$$A/A_0 = 1/2 = e^{-\lambda t}$$

then:

$$\ln(0.5) = -\lambda t$$

$$t_{1/2} = \ln(0.5) / (-\lambda)$$

$$= 0.6931 / \lambda$$

In practice, the Chart of the nuclides gives half life information for isotopes so the above equation may be used to calculate the decay constant. [1,2]

Radioactive Equilibrium - Radioactive equilibrium exists when a radioactive nuclide is decaying at the same rate at which it's being produced. Since the

production rate and the decay rate are equal, the number of atoms remains constant over time. Since a production term is required to achieve radioactive equilibrium this term is typically associated with an operating reactor core. Transient and secular equilibrium can occur for the intermediate radioactive isotopes in a naturally occurring radioactive decay chain. [2]

e. Describe the following neutron/nucleus interactions:
- Elastic Scattering
- Inelastic Scattering

A neutron scattering reaction occurs when a nucleus, after having been struck by a neutron, emits a single neutron. Although the initial and final neutrons may not be the same, the net effect of the reaction is as if the projectile neutron had merely "bounced off", or scattered from the nucleus. The two categories of scattering reactions, elastic and inelastic scattering are discussed below.

Elastic scattering - In an elastic scattering reaction between a neutron and a target nucleus, there is no energy transferred into nuclear excitation. Momentum and kinetic energy of the "system" are conserved although there is usually some transfer of kinetic energy from the neutron to the target nucleus. The target nucleus gains the amount of kinetic energy that the neutron loses. Elastic scattering is the most important mechanism for the slowing down of fast neutrons (by transferring kinetic energy to the target nucleus) while inelastic scattering plays a small role. Typically, fast neutrons undergo a series of elastic scattering where they lose energy until their kinetic energy is equal the kinetic energy due to the temperature of the medium they are in and they may then be referred to as thermal neutrons. The slowing down process is known as neutron moderation. [1,2,5]

Inelastic scattering - In inelastic scattering, the incident neutron is absorbed by the target nucleus, forming a compound nucleus. The compound nucleus will then emit a neutron of lower kinetic energy which leaves the original nucleus in an excited state. The nucleus typically undergoes one or more gamma emissions to drop from its excited state to its ground state. [2]

f. Compare and contrast capture (absorption), fission, and particle ejection nuclear reactions.

Capture, fission and particle ejection are known as absorption reactions because the parent nuclide absorbs a neutron to initiate the reaction. In a capture reaction (also known as radiative capture) the target nuclide absorbs a neutron and forms a compound nucleus that is in an excited state. The nucleus emits a gamma photon to eliminate its excitation energy and the newly formed

nuclide has one more neutron than the original nuclide. An example of a

capture reaction is: ${}^{1}_{0}n + {}^{1}_{1}H \rightarrow [{}^{2}_{1}H]^{excited} \rightarrow {}^{2}_{1}H + {}^{0}_{0}\gamma$. In a fission reaction the absorbed neutron causes the original nucleus to become unstable and split into two nuclei. A significant amount of energy (≈200 MeV) and approximately 2 or 3 neutrons are emitted in a typical fission reaction. An example of a fission reaction is: ${}^{1}_{0}n + {}^{235}_{92}U \rightarrow [{}^{236}_{92}U]^{excited} \rightarrow {}^{147}_{57}La + {}^{87}_{35}Br + 2\ {}^{1}_{0}n + {}^{0}_{0}\gamma$. In this reaction the Lanthanum and Bromine nuclides are referred to as fission fragments or fission products. Many different combinations of fission products are possible however the most common products have atomic mass numbers around 95 and around 140. In a particle ejection reaction the incident neutron enters the target nucleus exciting it to a high enough energy level to cause it to eject a new particle while the incident neutron remains in the nucleus. An example of a particle ejection reaction is: ${}^{1}_{0}n + {}^{10}_{5}B \rightarrow [{}^{11}_{5}B]^{excited} \rightarrow {}^{7}_{3}Li^{-2} + {}^{4}_{2}\alpha^{+2}$. In capture, fission and particle ejection reactions the target nucleus absorbs a neutron and becomes an excited nucleus, however the difference in the reactions occurs in the mechanism by which the excited nucleus gives off the excess energy. [1,2,5] It should be noted that less common, but similar, capture, fission and particle ejection reactions can be initiated by protons, heavy ions and photons.

1.3 Personnel shall demonstrate knowledge of the basic fission process and results obtained from fission.

a. Explain the fission process using the liquid drop model.

The liquid drop model considers the fissioning of a nucleus similar to the splitting of a liquid drop. A liquid drop is held together by molecular forces which tend to make the drop spherical in shape and resist deformation. The molecular forces within a liquid drop can be considered analogous to the nuclear forces within a nucleus. Using this model the fission process can be described. Initially, the nucleus is in an undistorted ground state with nuclear forces which are greater than the repulsive electrostatic forces of the protons within the nucleus. After a neutron is absorbed by the nucleus, a compound nucleus exists in an excited state. The measure of how far the energy level of a nucleus is above its ground state is called the excitation energy. For fission to occur, the excitation energy must be above a particular value for that nuclide. The critical energy (E_{crit}) is the minimum excitation energy required for fission to occur. The excitation energy added to the nucleus is equal to the binding energy of the neutron plus the kinetic energy of the neutron. If the excitation energy is greater than the critical energy for the nucleus in question than the nucleus may begin to oscillate and become distorted. If the oscillations are severe enough the nucleus may become dumb-bell shaped. The attractive nuclear forces in the “neck” of the nucleus may become saturated and because they can only act over a short distance (≈10^{-13} cm) the repulsive electrostatic forces in each end of the “dumb-bell” shaped nucleus may overcome them. When this occurs the nucleus splits

or fissions at its weakest point, the “neck”. [2]

b. Compare and contrast the characteristics of fissile material, fissionable material, and fertile material.

A nuclide which can be fissioned by neutrons of any energy level is considered to be a fissile material. Thus fissile material can fission after absorbing a thermal neutron with near zero kinetic energy. For a fissile isotope, the change in binding energy (ΔBE) caused by absorbing a neutron will provide enough excitation energy to a nucleus to exceed the minimum critical energy (E_{crit}) required to cause fission. Thus for fissile material $\Delta BE \geq E_{crit}$. Because fissile material can fission with neutrons of all energies, it is capable of sustaining a chain reaction where neutrons produced in a fission go on to cause additional fissions. Uranium-235, Uranium-233 and Plutonium-239 are examples of fissile material.

Fissionable material is composed of nuclides which can fission after absorbing a neutron, but for some isotopes (fissionable, non-fissile) the neutron must possess a minimum amount of kinetic energy. Fissile material is a subset of fissionable material thus all fissile materials are also fissionable. Isotopes which are not fissile and require an incident neutron with greater than thermal energy to cause a fission are fissionable, non-fissile isotopes. The critical energy for fissionable, non-fissile isotopes is greater than the binding energy associated with the absorption of a neutron, thus the neutron must also posses kinetic energy which can be transferred into the nucleus to make the excitation energy greater than the critical energy. Simply stated, the change in binding energy plus the kinetic energy must be greater than or equal to the critical energy: $\Delta BE + KE \geq E_{crit}$. Uranium-238, Plutonium-240 and Thorium-232 are examples of fissionable, non-fissile materials. Uranium-235, Uranium-233 and Plutonium-239 are examples of fissionable, fissile materials.

Fertile material is material which can be converted into fissile material. The conversion process begins when an isotope absorbs a neutron and a new isotope is created (transmutation). Subsequent radioactive decays or additional transmutations can occur to change the nucleus into yet other isotopes. When the final product of the nuclear transformations is a fissile isotope then the original target isotope is said to be fertile. Fertile materials must be exposed to a neutron flux (i.e.: an operating nuclear reactor) in order to begin the conversion process. Examples of fertile material are Thorium-232 and Uranium-238 which can be converted into Uranium-233 and Plutonium-239 respectively. The process for $^{238}_{92}U$ is as follows:

$$^{238}_{92}U + {}^{1}_{0}n \rightarrow {}^{239}_{92}U + {}^{0}_{0}\gamma$$
$$^{239}_{92}U \rightarrow {}^{239}_{93}Np + {}^{0}_{-1}\beta + {}^{0}_{0}\upsilon‘$$
$$^{239}_{93}Np \rightarrow {}^{239}_{94}Pu + {}^{0}_{-1}\beta + {}^{0}_{0}\upsilon‘$$

c. Discuss the various energy releases that result from the fission process.

Two of the numerous possible reactions which occur when $^{235}_{92}U$ fissions are shown below:

$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{54}Xe + ^{94}_{38}Sr + 2^{1}_{0}n + ^{0}_{0}\gamma$$
$$^{235}_{92}U + ^{1}_{0}n \rightarrow ^{140}_{55}Cs + ^{93}_{37}Rb + 3^{1}_{0}n + ^{0}_{0}\gamma$$

The released energy is distributed among the products of the reaction. Most of the energy is released immediately (≈ 89%) while the remainder is released over time as the fission products undergo radioactive decay. The immediate and delayed useful energy released by the fission of Uranium, Thorium or Plutonium is approximately the same and is about 200 MeV per fission. A portion of the delayed energy (≈10 MeV) is released to neutrinos which do not readily interact with matter and is not considered as useful energy. The average energy distribution for fission reactions is shown below:

Instantaneous Energy:	Kinetic Energy of fission products	167 MeV
	Energy of fission neutrons	5 MeV
	Instantaneous Gamma Photons	5 MeV
	Capture Gamma Photons	10 MeV
Total Instantaneous Energy		187 MeV
Delayed Energy:	Fission Product Beta Decay	7 MeV
	Fission Product Neutrinos	10 MeV
	Fission Product Gamma	6 MeV
Total Delayed Energy		23 MeV
Total Energy per fission		210 MeV
Total Useful Energy per fission		200 MeV

It is important to note that the majority of the energy released in a fission reaction is ultimately converted to heat energy and transferred to the material surrounding the fission site.

d. Define criticality and explain how it is detected.

Criticality can be defined as the state of a system of fissionable material where on average exactly one of the several neutrons emitted during a fission event causes another fission event to occur. The other fission neutrons are absorbed without causing a fission or they travel out of the system. When a system (or reactor) is exactly critical the power output of the system is constant. Criticality depends on geometric factors as well as the nature and distribution of the material in the system. If an average of more than one fission neutron survives

to cause additional fission events than the system is supercritical and the power output is increasing. If an average of less than one fission neutron survives to cause additional fission events than the system is subcritical and the power output is decreasing. [5] Thus the ratio of the number of neutrons in the next generation to the number of neutrons in the current generation (the effective neutron multiplication factor) can be used to describe if the system is critical, supercritical or subcritical. Mathematically:

$$k_{eff} = N_{i+1} / N_i$$

where: k_{eff} is the effective neutron multiplication factor
N_{i+1} is the number of neutrons in the next generation
N_i is the number of neutrons in the current generation

and: $k_{eff} > 1$ is a supercritical system
$k_{eff} = 1$ is a critical system
$k_{eff} < 1$ is a subcritical system

(A more detailed explanation of the neutron life cycle and k_{eff} including the 4 factor and 6 factor equations for k_{eff} can be found in DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, volume 2 of 2, Module 3, Reactor Theory, DOE-HDBK-1019/2-93)

Criticality in a fissile material processing facility could occur as a result of a criticality accident and would be detected by a Criticality Alarm System installed in accordance with the American National Standard, Criticality Accident Alarm System ANSI/ANS 8.3 of 1986. Various systems which have been designed to detect the neutrons, the gamma photons or a combination of the types of radiation emitted from a criticality accident are in use through out the DOE complex. The criticality alarm system at Rocky Flats is designed to detect thermal neutrons using a Lithium Fluoride (LiF) crystal and a diffused junction semiconductor detector. The system detects the charged particles created by the following neutron reaction: $^{1}_{0}n + {}^{6}_{3}Li \rightarrow {}^{4}_{2}He^{+2} + {}^{3}_{1}H^{+1} + 3e^{-1}$

Criticality in a reactor plant can be detected by installed nuclear instrumentation designed to measure the flux of thermal neutrons in the reactor core. The reactor is actually brought to a state of slight supercriticality where the measured neutron flux can be seen to increase at constant rate as measured on a logarithmic scale.

e. List five factors that affect criticality.

Eight factors have been identified that can be controlled in order to ensure that a system containing fissionable material stays subcritical. The eight factors are

interdependent thus a change in one factor will probably affect one or more of the others. The eight factors are: mass, volume, shape, density, moderation, reflection, neutron poisons and interaction.

Mass - The potential for fission to occur increases as the mass and hence the number of fissionable target atoms increases. A critical mass is the minimum amount of fissionable material that will support a chain reaction ($k_{eff} \geq 1$) under a given set of conditions.

Volume - As the size of a container increases, it can hold more fissionable material and the probability of neutrons escaping from the container decreases therefore the probability of a criticality increases with volume.

Shape - The shape of a container affects the ability of neutrons to escape from the container. Containers with a large surface area to volume ratio (i.e.: a long thin cylindrical tank) will allow more neutrons to leak out and thereby reduce the probability of a criticality accident. A sphere has the lowest possible surface area to volume ratio therefore it is the worst shape for maintaining a system in a subcritical state.

Density - Density is a measure of the mass per unit volume. As the fissionable material becomes more dense the probability of a neutron interacting with a fissionable atom and causing fission increases.

Moderation - The probability of a neutron interacting with a fissionable atom increases greatly when the neutron has slowed to thermal velocities. Thus when a neutron is slowed down or moderated it will increase the probability of fission in a fissile material (i.e.: $^{235}_{92}U$). Fissionable, non-fissile isotopes (i.e.: $^{238}_{92}U$) will have an increased probability of fission as the neutrons are moderated, but once the neutron energy drops below a specific value for the isotope in question the neutron will no longer be capable of causing fission. The maximum slowing down of neutrons per collision occurs when the neutrons collide with a nucleus of similar mass. Thus any material that contains light nuclei with low atomic mass numbers (i.e.: H, He, Li, Be etc.) are the best moderators. Water, oil and plastics all contain hydrogen atoms and may be referred to as hydrogenous materials, therefore they are examples of good moderators.

Reflection - Escaping neutrons will continue to move away from a fission site until they collide with a nucleus. If they leak out of the fissionable material they can collide with a nucleus of a reflector and be reflected back into the fissionable material to cause a fission. Materials that do not absorb neutrons will act as reflectors. Water is an excellent reflector as are most building materials used in a DOE nuclear facility (i.e.: steel, glass, lead, etc.).

Neutron Poisons are atoms that are effective at capturing or absorbing neutrons but are also non-fissionable. By capturing neutrons these nuclides can “poison”

a fission chain reaction and cause it to stop by removing neutrons. Neutron poisons commonly used include: Boron, Cadmium, Gadolinium and Chlorine.

Interaction occurs when neutrons from one fissionable system can travel to and interact with another fissionable system. When two or more subcritical systems are brought into close proximity of one another they may become critical because they may gain neutrons from the other system. [6]

f. Identify the hazards that result from an unwanted criticality.

An unwanted criticality is also referred to as nuclear criticality accident, which is an unintentional, uncontrolled nuclear fission chain reaction ($k_{eff} > 1$). If a criticality accident occurs, it releases a large amount of energy in the form of radiation and heat. Reactor facilities are designed for intentional controlled criticalities and therefore have adequate radiation shielding and containment of the fissionable material to ensure worker safety. Because fissionable material processing facilities are not designed with the shielding and containment of a reactor facility a criticality accident can pose serious health and safety risks to the workers. Some of the possible consequences of a criticality accident include:

1. Intense radiation exposures capable of causing death or biological injury to personnel.
2. Potential for the release of gaseous radioactive fission products to the environment (Radioactive fission produces noble gases like Radon, Xenon, Krypton etc. that pass through HEPA filters.)
3. Physical damage to the facility. A criticality accident would probably result in the breach of a glovebox containment system and the heat released may cause a fire.
4. Radioactive contamination of the facility due to a breach of containment and due to neutron activation of nearby material.

An individual in the vicinity of a criticality accident may observe the following: a blue flash, the criticality alarm system is activated (tone + beacons), physical damage to equipment, an ozone smell, heat, fire and the boiling of liquid for a fissile solution criticality. Assuming minimal shielding, the probable adverse health effects for an individual in the vicinity of a criticality accident are largely dependent upon the distance of the individual from the accident and to a much lesser extent are dependent upon the time for the individual to evacuate. For personnel within one foot of a criticality accident death is expected to occur within 48 hours. For personnel one foot to 15 feet from the accident death is expected 50% of the time and survivors will experience radiation sickness, temporary sterility, increased cancer risk, and increased cataract risk. Personnel 15 to 100 feet from the accident may experience radiation sickness and will have an increased cancer risk. Personnel located over 100 feet away

from the accident will suffer very little effect. [6]

g. Explain the double contingency principle as it relates to criticality control.

The double contingency principle is a means of administratively controlling and minimizing the probability of a criticality accident. The double contingency principle states: Process designs must incorporate sufficient safety factors so that at least two unlikely, independent and concurrent changes in process conditions must occur before accidental nuclear criticality is possible. In other words, compliance with the double contingency principle will ensure a sufficient safety margin so that no single credible process upset (accident) can result in a criticality accident. [6]

Endnotes/References:

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[2] U.S. Department of Energy, *DOE-HDBK-1019/1-93, DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Module 1, Atomic and Nuclear Physics*, (Oak Ridge, TN: Office of Scientific and Technical Information, 1993)
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[5] James E. Turner, *Atoms, Radiation, and Radiation Protection*, (Elmsford, NY: Pergamon Press Inc., 1986), ISBN: 0-08-031949-1.
[6] Rocky Flats Environmental Technology Site, *Nuclear Criticality Safety Training for Supervisors, Student Guide (SG# 023-420-01), Revision 0*, (Golden, CO: EG&G Rocky Flats, Inc., 1994).

SECTION 2: RADIOLOGICAL FUNDAMENTALS

2.1 Personnel shall demonstrate knowledge of radiological controls, practices, procedures and theory.

a. Define ionizing radiation.

Radiation is defined as the emission and movement of energy through space and or matter. Ionizing radiation is defined as radiation capable of causing the creation of ions as it passes through matter. Ions may be created directly by charged particles ($^{4}_{2}\alpha^{+2}$, β^{-} or β^{+}) interacting with the orbital electrons or they may be created indirectly during reactions involving uncharged particles ($^{1}_{0}n$), gamma ($^{0}_{0}\gamma$) photons or X-ray photons. Low energy photons (or electromagnetic radiation) such as visible light or AM radio signals do not have enough energy to cause ionization and are referred to as non-ionizing radiation. The distinction between ionizing and non-ionizing radiation is important because ionization is the primary mechanism by which radiation causes biological damage. [1]

b. Describe how nuclear radiation is generated.

Nuclear radiation can occur naturally or it can be man-made. Naturally occurring radiation may also be referred to as natural background radiation and it accounts for the majority of the radiation dose received by the average US citizen. The four major sources for naturally occurring radiation exposure are: cosmic radiation, terrestrial radiation, internal sources and Radon. Cosmic radiation consists of gamma photons and charged particles emitted from the sun and other stars. Terrestrial radiation is radiation originating from material in the earth's crust that contains radioactive elements such as Uranium, Radium and Thorium. Internal sources are naturally occurring radioactive isotopes such as Potassium-40, Carbon-14 and Sodium-24 that are present in the food we eat and the water we drink. Radon is a naturally occurring gas that is produced when Radium in the earth's crust undergoes radioactive decay. Radon gas travels up through the soil and tends to collect in buildings and homes. If Radon is inhaled and it subsequently decays while in the lungs, it results in a radiation exposure to the lung tissue. On average U. S. citizens receive the following radiation exposures from naturally occurring sources:

Cosmic	28 mrem
Terrestrial	28 mrem
Internal	40 mrem
Radon	200 mrem
Total	296 mrem

The four major sources of man-made radiation exposure are: medical radiation, atmospheric testing of nuclear weapons, consumer products and industrial uses. Medical radiation consisting of x-rays, radiation therapy for cancer, and the ingestion of radioactive medical sources comprises the largest man-made radiation exposure source. Atmospheric testing of nuclear weapons is now largely banned, however the residual radioactive fallout from testing in the 1950's and 1960's can still be measured and contributes a small amount to the radiation exposure from man-made sources. Consumer products such as smoke detectors, televisions, older luminous dial watches, older orange paint pigment and camping lantern mantels are examples of products which can emit radiation. Examples of industrial radiation sources include nuclear power plants, coal power plants, radiography equipment (used to X-ray metal welds etc.) and soil compaction test equipment. On average U. S. citizens receive the following radiation exposures from man-made radiation sources:

Medical	54 mrem
Atmospheric Testing	< 1 mrem
Consumer Products	10 mrem
Industrial	< 1 mrem
Total	≈ 65 mrem

Thus the average US citizen receives a total radiation dose of approximately 360 mrem per year. The average annual total radiation dose in Colorado is approximately 450-500 mrem per year. [1]

c. Describe each of the following forms of radiation in terms of structure, electrostatic charge, interactions with matter, and penetration potential:

Alpha - An alpha particle ($^{4}_{2}\alpha^{+2}$) contains 2 protons and 2 neutrons and has a +2 charge and a mass of approximately 4 atomic mass units (amu). An alpha particle has the same structure as a Helium nucleus and may also be indicated by the symbol $^{4}_{2}He^{+2}$. Alpha radiation occurs as a result of an isotope undergoing radioactive decay and ejecting an alpha particle from its nucleus. Because an alpha particle has a +2 charge, when it travels through matter it interacts vigorously by stripping electrons from nearby atoms and ionizing the atoms. The penetration potential of an alpha particle is very limited because its +2 charge causes it to quickly deposit its energy in a short travel distance within the matter. The penetration potential of an alpha particle in air is approximately one to two inches. [1,2] It should be noted that many nuclides that decay by Alpha emission also emit gamma photons (generally of low energy) during the decay process.

Gamma - Gamma radiation consists of photons or discrete bundles of electromagnetic energy which are emitted from the nucleus of a radioactive

isotope as it transitions from an excited state to a lower energy state (or ground state). Gamma radiation often accompanies Alpha decay and Beta decay and it always accompanies fission. Gamma photons have no mass and no charge and are indicated by the symbol $^{0}_{0}\gamma$. X-rays are similar to gamma rays however X-rays are emitted from the electron orbital shells and they typically have lower energy levels than gamma photons. Gamma and X-ray photons have no mass and no charge therefore they interact weakly with matter. The type of interaction can vary depending upon the energy level of the photon. In a process referred to as the photo-electric effect, low energy photons can collide and be absorbed by orbital electrons which are subsequently ejected from the atom. Medium energy photons typically undergo Compton scattering when they collide with orbital electrons and transfer energy to the electron which may cause the electron to be ejected from the orbital shell (Compton electron) while the photon continues on at a lower energy and on a new trajectory. High energy photons (above 1.02 MeV) can interact with heavy nuclei resulting in the annihilation of the photon and the production of an electron and a positron which is known as pair production. Unlike charged particles which have a maximum penetration range in a given material, photon penetration in matter is dependent upon the probability of interaction per distance traveled. Thus over time some photons can be expected to penetrate even the thickest materials. The amount of photons penetrating a material decreases exponentially as the penetration depth increases. [2,3]

Beta - Beta radiation occurs as a result an element undergoing Beta-Minus (β^-) or Beta-Plus (β^+) decay and the nuclei emitting Beta particles. The characteristics of the radiation produced by β^+ particles (positrons) and β^- particles (electrons) are very similar, therefore they can be discussed together. Both particles have a mass of $\approx$ 0.00055 amu and a charge with a magnitude of 1, but opposite signs. The majority of Beta radiation occurs as β^- particles because the electron capture process competes against the β^+ decay process limiting the number of β^+ decays and the majority of fission products from nuclear reactors decay by β^- emission. Beta particles can cause ionization by colliding with orbital electrons and displacing them from their parent atom. Each collision causes the β particle to slow down. Eventually β^- particles are captured in an atom's orbital shell and become an orbital electron. β^+ particles eventually combine with an orbital electron and both are mutually annihilated which results in the production of two 0.511 MeV gamma photons. In addition to collision reactions, β particles can be slowed when they pass through an electrostatic field within an atom. Because of the small mass of a β particle, its path can easily be changed if it passes through the electric field which closely surrounds the nucleus or the orbital electrons. If this occurs the β particle will be slowed, its path will be deflected and a gamma photon will be emitted. Photons produced in this fashion are referred to as Bremsstrahlung (or breaking) radiation. The

penetration potential of a β particle is limited because its charge causes it to quickly deposit its energy in a short travel distance within matter. The penetration potential of a β particle in air is approximately ten feet. [1,2,3] It should be noted that most nuclides that decay by Beta emission also emit gamma photons (of various energies) during the decay process.

Neutron (slow and fast) - Neutron radiation consists of neutrons ejected from the nucleus of an atom. Fission reactions in a nuclear reactor or nuclear weapon detonation are the most significant sources of neutron radiation. A neutron has no electrical charge and has a mass of approximately 1 amu. Because they are uncharged particles, neutrons can travel appreciable distances without interacting with matter. Neutron interactions occur when a neutron collides with the nucleus of an atom. After a collision the neutron can be elastically scattered, inelastically scattered, or absorbed by the nucleus. If the neutron is absorbed it can cause a variety of different reactions such as the emission of a gamma photon, the emission of an alpha particle, the emission of a proton or fission of the nucleus. In addition to collision reactions, neutrons can β^- decay with a 10.4 minute half life. Absorption, inelastic scattering and neutron decay reactions are responsible for the generation of charged particles and gamma photons which can cause ionization in matter. Neutrons are ejected from nuclei with a significant amount of kinetic energy and are referred to as fast neutrons when their energy level is greater than about 0.1 MeV. Neutrons loose energy through scattering reactions and when the energy is between 1 eV and 0.1 MeV they may be referred to as slow or resonance or intermediate neutrons. When the energy level has dropped below 1 eV the neutrons are referred to as thermal neutrons. The kinetic energy of a thermal neutron is due to the temperature of the material it is in. If the temperature is 20°C the most probable energy is approximately 0.025 eV. Thermal neutrons are more readily absorbed than higher energy neutrons which tend to undergo scattering reactions. The penetrating power of neutron radiation is significant. Neutrons can easily travel several hundred feet in air and like gamma radiation neutron radiation decreases exponentially with penetration distance. [1,2]

d. Discuss the types of materials that are best suited for shielding the above radiation types.

Alpha - Alpha radiation can be easily shielded and completely stopped by a sheet of paper or the dead layer of human skin.

Beta - Beta radiation is relatively easy to shield and like alpha it can be completely stopped, however slightly thicker materials are required. A few millimeters of metal will stop even the most energetic β particles. Plastic, glass, metal and foil are examples of materials which may be used for shielding.

Gamma - Gamma and X-ray radiation are best shielded by very dense materials such as lead, steel or concrete. Unlike charged particles, gamma photons can not be completely stopped. Some fraction of the incident gamma photons will pass through the shield. The decrease in the gamma radiation is dependent upon the energy of the photons, the type of shield material and the thickness of the shield. For a specific material and photon energy the amount of shielding required to reduce the radiation to one tenth of its original value is referred to as the tenth thickness. For 4 MeV photons and lead shielding the tenth thickness is approximately 2 inches. [2]

Neutron - Neutron radiation is best shielded by materials that contain a large amount of hydrogen atoms within their structure. These materials may be referred to as hydrogenous materials. Examples of hydrogenous materials include: water, plastic, paraffin, oil and other hydrocarbons. Hydrogenous materials make good neutron shields because neutron collisions with nuclei of nearly equal mass (i.e.: hydrogen) will allow the maximum energy transfer from the neutrons into the material. This allows the neutrons to be slowed down faster and with less collisions. After the neutrons have slowed they are more likely to be absorbed. The efficiency of a neutron shield can be increased by the addition of materials like Boron which have a high cross section for the absorption of neutrons. Unlike charged particles, neutrons can not be completely stopped. Some fraction of the incident neutrons will pass through the shield. The decrease in the neutron radiation is dependent upon the energy of the neutrons, the type of shield material and the thickness of the shield. In general neutron radiation decreases exponentially with penetration distance however resonance absorption of neutrons at specific energies makes it more difficult to calculate the behavior of a neutron shield than a gamma shield. [1,2,5]

e. Describe the biological effects and the primary hazards for each radiation type.

Alpha - Alpha particles are not considered an external radiation hazard because they are easily stopped by the dead layer of skin. If an alpha emitter is inhaled, ingested, absorbed or injected into the body it will emit alpha particles in contact with living cells and cause significant damage to a localized area. Thus alpha particles are primarily considered as an internal radiation hazard. Because the penetration power of an alpha particle is very limited, all of the particle's energy is deposited within a small distance. An alpha particle's +2 charge causes the displacement of many orbital electrons as the particle passes through tissue. This results in the creation of many ion pairs which can directly cause cell damage (i.e.: break a DNA strand) or subsequently form free radicals which can indirectly damage cells through chemical reactions (i.e.: H_3O^+ radical attacks DNA and breaks strand). [2]

Beta - Beta particles are considered an external radiation hazard to the skin and eyes, but they do not have enough penetration power to present a hazard to internal organs from an external source. If a beta emitter is inhaled, ingested, absorbed or injected into the body it can emit beta particles in contact with living cells and cause significant damage to a localized area. Thus beta particles are primarily considered as an internal radiation hazard. The mechanism for biological damage is the same as that of an alpha particle which is described above.

Gamma - Gamma radiation easily penetrates the whole body, therefore it is primarily considered as an external radiation hazard. If a gamma emitter is inhaled, ingested, absorbed or injected into the body it will emit gamma photons which will also cause a radiation exposure to the whole body. Although gamma radiation is uncharged, high energy photons will interact with matter and cause ion pairs to form. The ion pairs will subsequently cause biological damage as described in the section regarding alpha radiation.

Neutron - Neutron radiation easily penetrates the whole body, therefore it is primarily considered as an external radiation hazard. Although neutron radiation is uncharged, neutrons will interact with matter and cause ion pairs to form. The ion pairs cause biological damage as previously described.

f. Discuss radiation dose and how it is measured including the terms RAD, REM, Roentgen and international standard units (SI).

Some of the earliest measurements of the strength of gamma rays and X-rays were made by determining the amount ionization caused by the gamma or X-rays in air. Thus the ***roentgen (R)*** was defined as the amount of gamma or X-ray radiation that produces one electrostatic unit (esu) of charge in one cubic centimeter of air at Standard Temperature and Pressure (STP). The roentgen only describes the effects of gamma and X-rays in air and therefore is not a useful unit for describing the effects of all types of radiation on humans. The ***RAD or Radiation Absorbed Dose*** was developed to describe the amount of energy deposited by any type of radiation per unit mass in any kind of matter. The RAD was defined as 100 ergs of energy deposited per one gram of material (1 RAD = 100 ergs / gram). The RAD is a useful unit for describing the effects of radiation on humans. The newer ***SI unit for absorbed dose*** is the gray (Gy) which is defined as 1 Joule/Kilogram, thus 1 Gy = 100 RAD. Although different types of radiation may deposit the same amount of energy per gram of human tissue, the mechanism of energy deposition may differ and therefore the amount of biological damage may vary. The concept of dose equivalent was developed to describe the expected biological damage in humans from a specified quantity and type of radiation. Dose equivalent can be expressed in ***REM*** (Roentgen-Equivalent-Man) which is defined as a unit of dose equivalent equal to the

absorbed dose in RAD multiplied by the Quality Factor (Q) for the specific radiation in question. Thus, REM = Q x RAD. The ***SI unit for dose equivalent*** is the Sievert (Sv) and 1 Sv = 100 REM. In SI units, the dose equivalent is expressed as Sv = Q x Gy. [2] The correlation between RAD, REM, Gray, and Sievert is summarized below:

1 RAD = 100 ergs / gram	REM = Q x RAD
1 Gy = 1 Joule / Kilogram	Sv = Q x Gy
1 Gy = 100 RAD	1 Sv = 100 REM

g. Define Quality Factor and describe how it is used.

The quality factor is a dimensionless numerical value given to each type of radiation based upon its potential to cause biological damage. As discussed above, the Quality Factor (Q) is used to relate the absorbed dose to the dose equivalent. Thus REM = Q x RAD or for SI units Sv = Q x Gy. [1] Approximate Quality Factors for various forms of radiation are shown below: [9]

Radiation Type	Quality Factor
Gamma	1
X-ray	1
Beta	1
Neutrons $\leq$ 10 keV	3
Neutrons > 10 keV	10
Alpha	20

h. Define the term ALARA and describe the basic methods for achieving ALARA.

ALARA is an acronym for As Low As Reasonably Achievable. By striving to minimize the exposure of personnel to ionizing radiation the risk of adverse radiation induced health effects is also minimized. The ALARA policy is designed to prevent unnecessary radiation exposures and to ensure that there are no radiation exposures with out commensurate benefit. Any action that is reasonable and economical that can be taken to reduce radiation exposure must be done. Time, Distance and Shielding are three factors which can greatly affect the dose equivalent received by a radiation worker performing a given task. Basic methods for achieving ALARA consider these factors and seek to minimize exposure by reducing the time required to perform a task while in a radiation field, by maximizing the distance from a radiation source and by using shielding as appropriate to reduce the radiation at the work site. ALARA programs also employ a variety of administrative controls such as those to ensure radiation work is properly planned, coordinated and executed; to set

administrative control levels for the maximum allowable dose which are lower than those required by law or the DOE; to track the dose equivalent received by individuals and prevent them from exceeding established limits; to provide ALARA training and to audit compliance to the ALARA policy. [1]

2.2 Personnel shall demonstrate knowledge of contamination control, practices, procedures, and theory.

a. Define contamination and describe three types of contamination.

Radioactive contamination is the presence of radioactive material in an unwanted place. Radioactive contamination can occur as fixed surface contamination, removable surface contamination or airborne contamination or any combination of the three. Fixed contamination can not be readily removed from a surface. It can not be removed by casual contact, however it may be released if the surface is disturbed by activities such as buffing, grinding, sanding or cleaning with a volatile solvent. Over time fixed contamination may leach from the material containing it and become removable contamination. Removable or transferable contamination is radioactive material that can be easily removed from a surface. It may be transferred by any casual contact such as touching, wiping, or brushing. Radioactive material suspended in the air is referred to as airborne contamination and it can be caused by occurrences such as air movement over removable contamination, a leak from a radioactive system, grinding on a surface with fixed or removable contamination, or a fire involving radioactive material. [1]

b. Describe three ways to control contamination.

Engineering controls, administrative controls and personnel contamination control practices are used to control radioactive contamination. Engineering controls consist of structures or components designed to minimize or prevent the release of radioactive materials. Ventilation systems and containment systems are two examples of engineered controls. In general, ventilation systems are designed to move any potential airborne contamination away from personnel and to filter the radioactive material from the air. High Efficiency Particulate Air (HEPA) filters, personnel air locks, downdraft tables, hoods and air movers are examples of ventilation system components which are used to control contamination. Containment's are used to physically enclose radioactive material thereby preventing it from becoming contamination. Containment's include items such as vessels, pipes, cells, gloveboxes, glovebags, tents, huts, and plastic coverings. Administrative controls are used to direct the actions of personnel in order to minimize the risk of exposure to radioactive contamination. Examples of administrative controls include postings to control access to contaminated areas and procedures to minimize or prevent the production of

radioactive contamination. Personnel contamination control practices are measures taken to use personal protective equipment to prevent personnel from becoming contaminated with radioactive material and they include: the use of precautionary clothing, Anti-Contamination clothing (Anti-Cs), and respiratory equipment. [1,7]

c. Describe how contamination is detected.

Surface contamination is monitored for by Radiological Control Technicians (RCTs) who are required to routinely survey areas for potential contamination. At Rocky Flats contamination monitoring equipment is primarily used to detect alpha particles, however monitoring for beta particles and gamma also occurs. Surface contamination may be detected either by a "direct frisk" (holding the probe of a radiation detection instrument just above the monitored surface) or by "smearing" or "swiping" the surface with a paper or cloth swipe and monitoring the swipe for contamination. Direct frisking will detect fixed or removable contamination while smearing will only detect removable contamination. When surface contamination is detected using the direct frisk method a smear of the contaminated surface is taken to determine if the contamination is fixed or removable. Airborne contamination is detected by specialized air monitoring equipment. Airhead samplers contain filters and are connected to vacuum systems so that the air being sampled will flow through the filter while any particulate airborne radioactive contamination present will deposit on the filter. The filters are periodically removed and measured for radioactive contamination. Airhead samplers produce very accurate measurements of airborne contamination, however they do not provide a timely indication of airborne contamination to warn workers. A Selective Alpha Air Monitor (SAAM) is a type of continuous air monitor used at Rocky Flats to measure airborne radioactive contamination and warn workers if the level rises above the alarm setpoint. Portable air samplers may also be used to measure airborne contamination if permanently installed SAAMs do not provide adequate coverage during maintenance or other activities. [1,6]

d. Describe three ways contamination could enter the body and the methods used to prevent internal contamination.

Radioactive contamination can enter the body in four ways:

1. Inhalation - breathing in radioactive material.
2. Ingestion - eating or drinking radioactive material.
3. Injection - radioactive material enters the body through an open wound or as a result of bodily injury such as a puncture wound.
4. Absorption - radioactive material absorbed through the skin.

Internal contamination can be prevented by the proper use of contamination control practices and in particular the use of engineering controls to isolate

radioactive material from personnel. In some instances however, personal protective equipment must be used as the last line of defense against internal contamination. In these cases respiratory equipment (respirators, supplied air, Self Contained Breathing Apparatus (SCBA) etc.) with an adequate protection factor can be used to prevent the inhalation or ingestion of radioactive material. Additionally, administrative controls to prohibit eating, drinking, smoking, and chewing tobacco may be used to minimize the risk of ingestion of radioactive materials. The risk of internal contamination by injection can be reduced by minimizing operations where a sharp contaminated object could pierce a containment and injure personnel. Additionally medical personnel are required to evaluate/decontaminate personnel wounds/cuts which occur to workers while they are in a Radiological Buffer Area, Airborne Radioactivity Area, Contamination Area or High Contamination Area. The risk of internal contamination by absorption can be reduced by the appropriate use of personal protective clothing and prompt decontamination of the skin. [1]

e. Describe the methods used for internal dose determination.

Bioassay samples, lung counting and wound counting are three methods used in monitoring for internal contamination. A routine bioassay program is required by 10 CFR 835 for personnel if there is a likelihood that an intake of radioactive material could occur that would exceed specific limits as specified in §835.402 (c). Bioassay programs use urine samples, fecal samples and nasal and mouth smears to determine the Committed Effective Dose Equivalent (CEDE) from internal contamination. Fecal samples are the most sensitive bioassay method for detecting internal plutonium contamination. The type of bioassay samples collected and the CEDE will depend upon many factors such as: the radionuclide involved, the chemical form of the material, the route of entry, and the elapsed time since the intake occurred. Lung counters are used to detect inhaled radioactive material in the lungs. The lung counter has a limited capacity for detecting internal contamination because it can only measure gamma rays. The amount of inhaled Plutonium must be estimated from the measured amount of gamma rays emitted from Americium (Pu decay product). Lung counts can be used in conjunction with bioassay samples to determine CEDE. Wound counters measure gamma and X-rays emitted by radionuclides deposited in a wound. Wound counts are primarily used as a tool to determine if internal contamination of a wound has occurred and to determine the successfulness of subsequent decontamination efforts. [1]

f. Describe the types of personal protective equipment.

In general, personal protective equipment used for radiological purposes can be divided into two main types; protection against internal contamination and protection against external contamination or sources. Respiratory protection is used to protect personnel from inhaling or ingesting radioactive material.

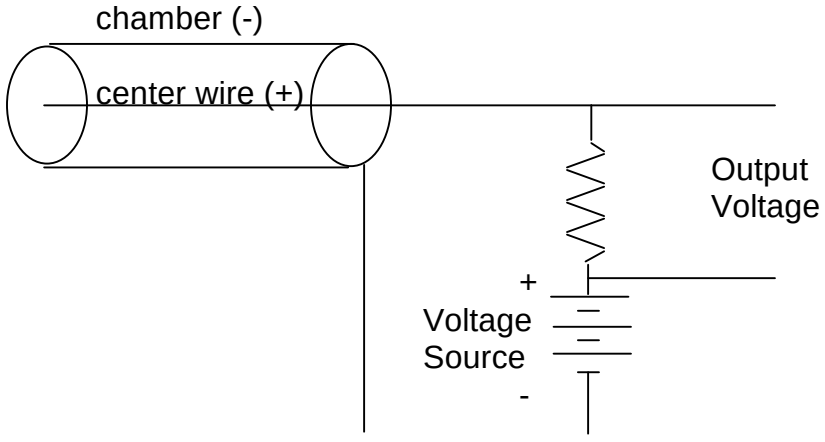
Respirators (with the appropriate cartridge), supplied breathing air and Self Contained Breathing Apparatus (SCBA) are examples of respiratory equipment used to prevent internal contamination. Protection factors are assigned to respiratory protection equipment which are used to determine the maximum level of airborne radioactive contamination that the equipment can protect

against. Examples of equipment used to protect against external contamination or radiation sources include: anti-contamination clothing (protection against skin contamination), safety glasses (protection against beta to the eye), lead aprons (protection against gamma to reproductive organs), and lead lined gloves (protection against skin contamination and gamma to hands). Requirements to use personal protective equipment are included in Radiological Work Permits and on postings at area entry points.

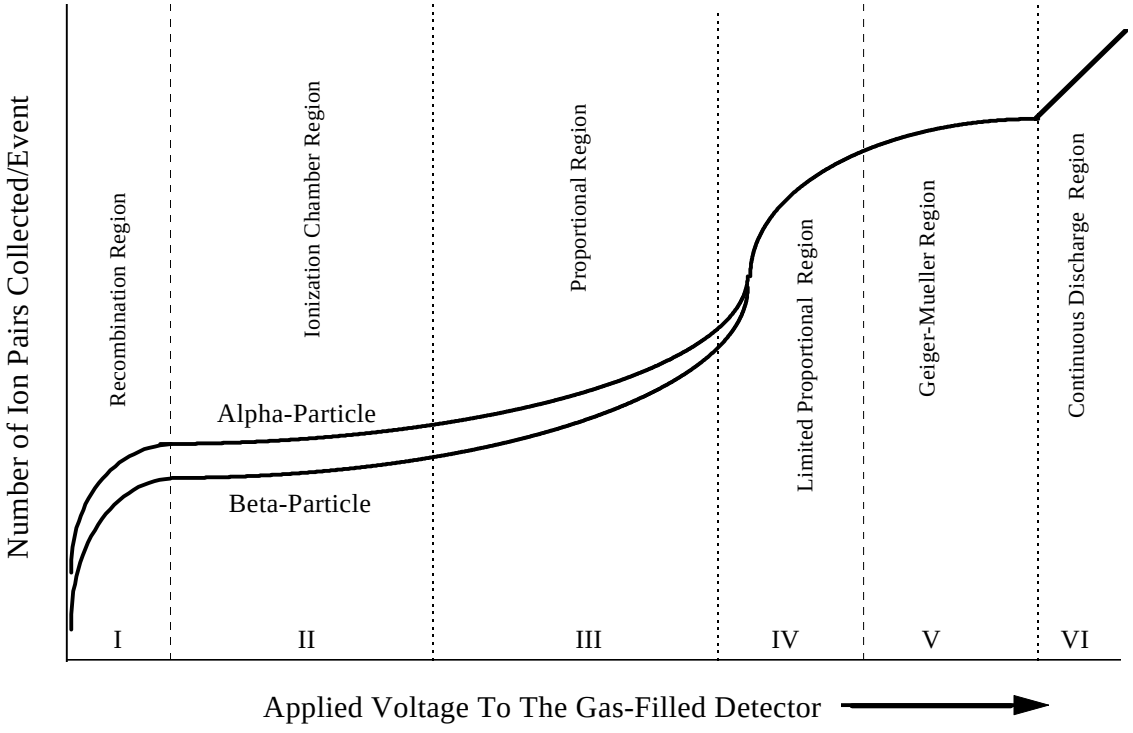
2.3 Personnel shall demonstrate knowledge of basic radiation detection methods and principles.

a. Describe the type of radiation detected and the method of radiation detection of the following radiation detection instruments:

Gas-filled detector - Gas filled detectors can be designed to detect any type of ionizing radiation (alpha, beta, gamma, or neutron). Gas filled detectors may be filled with air and open to the atmosphere or they may be filled with a specific gas (like Boron Trifluoride (BF_3) gas for neutron detection) and sealed. These detectors consist of a gas filled metal chamber (typically a cylinder) with a wire passing through the center of the chamber (see diagram below). A voltage source is connected to the detector with the positive terminal connected to the center wire and the negative terminal connected to the chamber or can. The voltage source causes an electric field to be set up throughout the chamber. When radiation enters the chamber and causes ionization of the gas, free electrons and positively charged ions are created. The electric field accelerates the electrons toward the center wire (anode) while the positively charged ions are accelerated towards the chamber walls (cathode). When electrons reach the center wire or positively charged ions reach the chamber walls they momentarily cause a current to flow and the detector output voltage to drop. Depending upon the voltage applied to the chamber, the chamber geometry, the chamber gas and the strength of the radiation field the current in the circuit may occur in pulses or as a relatively steady current. [2,8]



In a gas filled detector the number of ion pairs measured by the detector per ionizing radiation event is dependent upon the voltage applied to the detector. At low voltages an ionizing radiation event may not be detected because the ions may recombine before they reach the center wire or the detector can. The voltage range which allows ions to readily recombine is known as the recombination region. As the applied voltage increases, ion pairs undergo greater acceleration, attain higher velocities and travel to the center wire or the can without recombining. The voltage range which allows ions to reach the wire or can without recombining is known as the ionization chamber region. When the voltage is increased above the ionization chamber region, the ions have enough kinetic energy to create new ion pairs if they collide with gas molecules. These new ions are referred to as secondary ions and the amount of secondary ions created increases proportionally with increases in voltage and with the initial ions created by the radiation event. The increase in secondary ions is referred to as the gas amplification factor. The voltage range which allows the creation of secondary ions proportional to the primary ions is known as the proportional region. As the voltage is further increased the detector operates in the limited proportional region, however this region is not useful for radiation detection purposes. The voltage range above the limited proportional region is known as the Geiger-Müeller region. In the Geiger-Müeller region any ionization event in the chamber causes an avalanche of secondary ions which cause a momentary ionization of the entire chamber. A characteristic curve showing the relationship between the number of ion pairs collected per event and the detector voltage for gas filled detectors is shown below. [8]



Proportional Counter - A proportional counter is a gas filled detector operated in the proportional region. Some of the characteristics of a proportional counter are:
- The pulse size is proportional to the number of primary ionizations created.
- Slight changes in the detector voltage cause large changes in the pulse size.
- Primarily used to detect alpha radiation.
- Operates in a region where gas multiplication occurs.
- Has a short dead time before it can detect the next ionizing radiation event. [8]

Ionization Chamber - An ionization chamber is a gas filled detector operated in the ionization chamber region. Some of the characteristics of an ionization chamber are:
- The pulse size depends only on the number of primary ionizations created.
- Small changes in the detector voltage have little or no effect on the output.
- Primarily used to detect gamma and X-ray radiation.
- Operates in a region where no gas multiplication occurs.
- Most accurate region of gas filled detector operation. [8]

Geiger-Müeller Detector - A Geiger-Müeller detector is a gas filled detector operated in the Geiger-Müeller region. Some of the characteristics of a Geiger-Müeller detector are:
- The pulse size is independent of the number of primary ionizations created.
- Primarily used to detect beta and gamma radiation.
- Operates in a region where avalanche occurs.
- Has a long dead time before it can detect the next ionizing radiation event.
- Most sensitive region of gas filled detector operation. [8]

Scintillation Detector - Luminescence is the process whereby energy is absorbed by a substance and then re-emitted as visible light. This process is used to detect radiation with a scintillation detector. Incident radiation interacts with the scintillation material causing ionization and excitation of the electrons. The de-excitation of the scintillator electrons results in a visible light pulse. A photomultiplier tube is used to convert the light pulses to an electrical signal which is fed into circuitry and subsequently displayed as a count rate. Scintillation detectors can be designed to detect alpha, beta, gamma or neutron radiation. [8]

b. Describe the proper use, function and radiation detected by different types of Thermoluminescent Dosimeters and Pocket Ion Chamber.

Thermoluminescent dosimeters (TLD) are used to measure the external radiation dose received by radiation workers (personnel with the potential to receive $\geq$ 100 mrem/yr whole body effective dose equivalent from occupational exposures). The whole body dosimeter used at Rocky Flats contains two TLDs.

One is used to measure exposure to beta, gamma, X-ray and neutron radiation while the other is used to measure only neutron radiation exposure. Each TLD contains material which absorbs and stores the energy of the applicable radiation and when heated gives off the energy as ultra violet light in proportion to the quantity of radiation exposure received. By measuring the ultra violet light given off by the TLD, the effective dose equivalent received by the wearer of the TLD can be calculated. Whole body dosimeters are worn on the chest area between the waist and the neck with the picture (and the beta window) facing out. Dosimeters are stored on assigned badge storage racks when not in use. In addition to whole body TLDs, wrist TLDs are worn by workers who work in gloveboxes or directly handle radioactive materials and must be monitored for extremity (hands and arms below the elbow; feet and legs below the knees) exposure.

Pocket Ion Chamber dosimeters are also known as direct reading dosimeters, self reading pocket dosimeters or pocket dosimeters. They are used to measure gamma or X-ray radiation and are used in conjunction with whole body TLDs. Pocket Ion Chambers (or another type of supplemental dosimeter) are required to be worn by workers entering high or very high radiation areas where they could receive $\geq$ 10% of an administrative control level in one work day. The advantage of a pocket ion chamber dosimeter over a whole body TLD is that they can be read by the wearer allowing the wearer to closely monitor their radiation exposure while they are working in a radiation field. Pocket ion chambers are worn adjacent to whole body TLDs.

c. State the purpose and function of the following radiation monitoring systems:

Criticality - The purpose of a criticality alarm system is to alert personnel in a facility if a criticality accident occurs. Criticality alarm systems are installed in accordance with ANSI/ANS 8.3, Criticality Accident Alarm System in facilities where a criticality accident is credible. If a criticality accident occurs, large amounts of neutron and gamma radiation are released. The criticality alarm system detects the radiation and activates audible and visual alarms. There are eleven criticality alarm systems in use at Rocky Flats.

Area - The purpose of an area radiation monitoring system is to alert personnel in an area of a facility if the radiation/dose rate in that area increases above a preset level. At Rocky Flats, area radiation monitors are used in Building 790 and in various radiography vaults.

Process - There are no process radiation monitoring systems in use at Rocky Flats.

Airborne - The purpose of an airborne radiation monitoring system is to alert personnel in an area of a facility if the air becomes contaminated with radioactive material. Airborne radiation monitoring systems typically pass air through a filter and then detect any radiation emitted from airborne particulate material deposited on the filter. The airborne radiation monitoring systems at Rocky Flats are designed to detect alpha radiation and are referred to as Selective Alpha Air Monitors (SAAM). There are approximately 350 SAAM units in use at Rocky Flats.

2.4 Personnel shall demonstrate knowledge of the requirements documents for radiological control practices, procedures and limits.

a. Discuss the purpose of 10 CFR 835.

10 Code of Federal Regulations (CFR) 835 is a rule promulgated by the Department of Energy (DOE) that implements radiation protection guidance for occupational exposure within federal agencies. The purpose section of the rule states: "...The final rule helps to ensure that DOE facilities are operated in a manner such that occupational radiation exposure to workers is maintained within acceptable limits and as far below these limits as is reasonably achievable. In general, this final rule codifies existing DOE radiation protection directives. This final rule provides nuclear safety requirements which, if violated, will provide a basis for the assessment of civil and criminal penalties under the Price Anderson Amendment Act (PAAA) of 1988."

b. Referring to the DOE Radiological Control Manual, locate and discuss the following requirements:

Access Training - Entry requirements including training requirements are stipulated in Chapter 3 - Conduct of Radiological Work, Part 3 - Entry and Exit Requirements, Articles 331 through 336. Additional information on training requirements can be found in Chapter 6 - Training and Qualification, Part 2 - General Employee Radiological Training, Part 3 - Radiological Worker Training, and Part 5 - Other Radiological Training. Copies of the applicable sections of the DOE Radiological Control Manual are attached at the end of this study guide section.

Access Requirements - Entry and exit requirements are stipulated in Chapter 3 - Conduct of Radiological Work, Part 3 - Entry and Exit Requirements, Articles 331 through 336. Copies of the applicable sections of the DOE Radiological Control Manual are attached at the end of this study guide section.

Dose Limits - Information and requirements regarding dose limits can be found in Chapter 2 - Radiological Standards, Part 1 - Administrative Control Levels and Dose Limits, Articles 211 through 216 and Appendix 2A. Copies of the applicable sections of the DOE Radiological Control Manual are attached at the end of this study guide section.

Posting types and use - Information and requirements regarding radiological postings can be found in Chapter 2 - Radiological Standards, Part 3 - Posting, Articles 231 through 237. Copies of the applicable sections of the DOE Radiological Control Manual are attached at the end of this study guide section.

2.5 Using references, personnel shall demonstrate knowledge of the purpose of the following DOE Orders:

1540.3A Base Technology for Radioactive Material Transportation Packaging Systems - This order has been superseded by DOE Order 460.2 Departmental Materials Transportation and Packaging Management. The objective (purpose) of DOE Order 460.2 is "to establish DOE policies and requirements to supplement applicable laws, rules, regulations and other DOE orders for materials transportation and packaging operations."

5400.5 Radiation Protection of the Public and the Environment - The purpose of this Order is to establish standards and requirements for operations within DOE to:

- maintain radiation exposures and radioactive contamination to members of the public within the limits established by this Order through management of real and personal property;
- minimize potential exposures to members of the public as far below the limits as is reasonably achievable (ALARA);
- ensure that DOE facilities have the capabilities, consistent with the types of operations conducted, to monitor routine and non-routine releases;
- assess doses to members of the public;
- to protect the environment from radioactive contamination to the extent practical.

N5480.6 Radiological Control Manual - This version of the Radiological Control Manual was superseded by DOE/EH-0256T, Revision 1, Radiological Control Manual. The purpose of DOE/EH-0256T Revision 1 as stated in article 112 is to establish

> "practices for the conduct of DOE radiological control activities. The manual states DOE's positions and views on the best courses of action currently available in the area of radiological controls. Accordingly the

provisions in the manual should be viewed by contractors as an acceptable technique, method or solution for fulfilling their duties and responsibilities. This manual shall be used by DOE in evaluating the performance of its contractors.

The manual is not a substitute for regulations; it is intended to be consistent with all relevant statutory and regulatory requirements and shall be revised whenever necessary to ensure such consistency. Some of the manual provisions, however, challenge the user to go well beyond minimum requirements. Following the course of action delineated in the manual will result in achieving and surpassing related statutory or regulatory requirements."

5480.11 Radiation Protection for Occupational Workers - This order was canceled by DOE Notice 441.1. This was part of a directives reduction effort to reduce the burden of unnecessary, repetitive, or conflicting requirements from various DOE Orders and Notices. DOE Notice 441.1, when combined with 10 CFR 835 and its associated implementation guidance, form the basis for a comprehensive radiological protection program. Notice 441.1 contains 16 top-level, performance-based requirements to provide critical direction in the areas of administrative controls, radiation safety training, work authorizations, postings, exposure of minors and sealed radioactive source accountability. This is consistent with the purpose of the superseded DOE Order 5480.11 which is to protect the worker from ionizing radiation.

5480.15 Department of Energy Laboratory Accreditation Program for Personnel Dosimetry - This Order was canceled by DOE Notice 441.1 as part of the directives reduction effort. The purpose of DOE Notice 441.1 is consistent with the purpose of the superseded DOE Order 5480.15 which is to ensure integrity of dosimetry results by establishing a dosimetry accreditation program. This program is based on an evaluation of a laboratory performance test that evaluates the dosimeter against established criteria and an onsite assessment of the quality assurance, documentation, and technical adequacy of the system.

PART 3 Entry and Exit Requirements

331 Controlled Areas

Successful completion of Visitor Orientation or General Employee Radiological Training is required for unescorted entry into Controlled Areas.

332 Radiological Buffer Areas

1. Minimum requirements for unescorted entry into Radiological Buffer Areas shall include the following:

   a. Radiological Worker I training
   b. Personnel dosimetry, as appropriate.

2. Personnel who exit a Radiological Buffer Area containing Contamination Areas, High Contamination Areas, or Airborne Radioactivity Areas should monitor as specified in Article 338.

333 Radioactive Material Areas

1. Radiological Worker I training shall be required for unescorted entry into Radioactive Material Areas containing either of the following:

   a. Sealed radioactive sources
   b. Radioactive material labeled and packaged in accordance with Articles 412 and 413

2. Entry into Radioactive Material Areas where whole body dose rates exceed 5 mrem/hr or removable contamination levels exceed Table 2-2 values shall be in accordance with the requirements of Articles 334.1 and 335.1, respectively.

334 Radiation, High Radiation and Very High Radiation Areas

1. Minimum requirements for unescorted entry into Radiation Areas shall include the following:

   a. Radiological Worker I training
   b. Worker's signature on the Radiological Work Permit (RWP), as applicable
   c. Personnel dosimetry.

2. Physical controls to prevent inadvertent or unauthorized access to High and Very High Radiation Areas shall be maintained in accordance with Appendix 3B.

3. Minimum requirements for unescorted entry into High Radiation Areas shall include the following:

   a. Radiological Worker II training (or Radiological Worker I with High/Very High Radiation Area access training in accordance with Article 632.5) and training in the use of a survey meter (or dose rate indicating device), as described in Article 126
   b. Worker's signature on the RWP
   c. Personnel and supplemental dosimeters
   d. Survey meter or dose rate indicating device available at the work area.

4. Minimum requirements for unescorted entry into High Radiation Areas where dose rates exist such that a worker could exceed a whole body dose of 1 rem in one hour shall include those items listed in Article 334.3 and the following:

   a. A determination of the worker's current exposure, based on primary and supplemental dosimeter readings
   b. Pre-job briefing, as applicable
   c. Review and determination by the Radiological Control Organization regarding the required level of Radiological Control Technician coverage.

5. Workers shall be prevented from entry to Very High Radiation Areas when the radiation source is exposed and very high radiation fields are present. In addition to the controls required in Articles 334.2 and 334.3, a survey shall be made prior to the first entry to the area after the source has been secured or shielded to verify the very high radiation field has been terminated.

6. Facility operations personnel should be notified prior to personnel entry to areas where operational or system changes made by operations personnel could result in significantly increased area dose rates.

7. The number, issue and use of keys shall be strictly controlled where locked entryways are used to control access to High and Very High Radiation Areas.

8. The Radiological Control Organization should maintain an inventory of High and Very High Radiation Areas.

9. Weekly inspections of the physical access controls to High and Very High Radiation Areas should be made to verify controls are adequate to prevent unauthorized entry.

10. Administrative procedures shall be developed as necessary to implement area access controls. These procedures shall address measures implemented to ensure the effectiveness and operability of entry control devices, such as barricades, alarms, and locks.

335 Contamination, High Contamination and Airborne Radioactivity Areas

1. Minimum requirements for unescorted entry into Contamination Areas shall include the following:

   a. Radiological Worker II training
   b. Worker's signature on the RWP, as applicable
   c. Protective clothing
   d. Personnel dosimetry, as appropriate.

2. Minimum requirements for unescorted entry into High Contamination or Airborne Radioactivity Areas shall include the following:

   a. Radiological Worker II training
   b. Worker's signature on the RWP
   c. Protective clothing and respiratory protection when specified by the RWP
   d. Pre-job briefing for High Contamination or Airborne Radioactivity Areas, as applicable
   e. Personnel dosimetry, as appropriate.

3. Personnel exiting Contamination, High Contamination or Airborne Radioactivity Areas shall:

   a. Remove protective clothing as specified in Appendix 3C
   b. When entering an uncontaminated area, perform whole body frisking to detect personnel contamination in accordance with Article 338.

4. Exit points from Contamination, High Contamination or Airborne Radioactivity Areas should include the following:

   a. Step-off pad located outside the exit point, contiguous with the area boundary
   b. Step-off pads maintained free of radioactive contamination
   c. Labeled containers inside the area boundary for the collection of protective clothing and equipment
   d. Contamination monitoring equipment located as close to the step-off pad as background radiation levels permit.

5. Multiple step-off pads should be used at the exits from High Contamination Areas. Use of multiple step-off pads is described in Appendix 3C.

6. Protective clothing and monitoring requirements specific to benchtop work, laboratory fume hoods, sample stations and gloveboxes are identified in Article 347.

7. Tools or equipment being removed from areas posted for surface or airborne radioactivity control shall be monitored for release in accordance with Article 421 or for retention in the contaminated tool crib in accordance with Article 442.5.

8. Administrative procedures shall be developed as necessary to implement area access controls. These procedures shall address measures implemented to ensure the effectiveness and operability of entry control devices, such as barricades, alarms, and locks.

336 Visitor Entry Requirements

1. Site procedures shall identify area entry requirements and access restrictions for visitors.

2. Visitors with a demonstrated need to enter the following areas may be allowed access if such access is controlled with a combination of training and the use of escorts trained for the specific area:

   a. Radiological Buffer Areas
   b. Radiation Areas
   c. Contamination Areas
   d. Radioactive Material Areas

3. Visitors shall be prevented from entering Very High Radiation Areas in accordance with Article 334.5 and should be prohibited access to High Radiation, High Contamination and Airborne Radioactivity Areas.

4. Training requirements for visitors are identified in Articles 622 and 657.

PART 1 Administrative Control Levels and Dose Limits

The DOE's objective is to maintain personnel radiation exposure well below regulatory dose limits. To accomplish this objective, challenging numerical Administrative Control Levels are established below the regulatory limits to administratively control and help reduce individual and collective radiation dose. In general, efforts to reduce individual dose should not be allowed to cause a concurrent increase in collective dose. These control levels are multi-tiered with increasing levels of authority required to approve higher Administrative Control Levels.

With issuance of this Manual, the committed effective dose equivalent is used to assign internal dose received by personnel at DOE facilities. The committed effective dose equivalent is the resulting dose committed to the whole body from internally deposited radionuclides over a 50-year period after intake.

Unless otherwise indicated, administrative, lifetime and special control levels and dose limits are stated in terms of the sum of the doses received from internal and external sources.

211 Administrative Control Level

1. A DOE Administrative Control Level of 2,000 mrem per year per person is established for all DOE activities. Approval by the appropriate Secretarial Officer or designee shall be required prior to allowing a person to exceed 2,000 mrem.

2. An annual facility Administrative Control Level shall be established by the contractor senior site executive based upon an evaluation of historical and projected radiation exposures, work load and mission. The selection of the specific value shall be more restrictive than the DOE Administrative Control Level. This control level should be reevaluated annually. The choice of a low level for one year should not preclude choosing either a higher or lower level in a subsequent year.

3. For most facilities, an annual facility Administrative Control Level of 500 mrem or less should be challenging and achievable. An annual Administrative Control Level above 1,500 mrem is in most cases not sufficiently challenging to meet the goals of this Manual.

4. No person shall be allowed to go above the facility Administrative Control Level without the prior approval of the contractor senior site executive.

212 Lifetime Control Level

1. To administratively control a worker's lifetime occupational dose, a Lifetime Control Level of N rem shall be established where N is the age of the person in years. Special Control Levels (Article 216) shall be established for personnel who have doses exceeding N rem.

2. The internal contribution to lifetime occupational dose from intakes prior to January 1, 1989, should be calculated in terms of either cumulative annual effective dose equivalent or committed effective dose equivalent. The internal contribution to lifetime occupational dose should continue to be reassessed as further bioassay results and improved methods for assessing internal dose become available.

213 Radiological Worker Dose Limits

1. Dose limits are provided in Table 2-1 and shall not be exceeded. All occupational exposure received during the current year shall be included when demonstrating compliance with Table 2-1 dose limits. These regulatory limits are consistent with the "Radiation Protection Guidance to Federal Agencies for Occupational Exposure" signed by the President.

2. Radiological workers from other DOE or DOE contractor facilities may receive occupational exposure as a radiological worker if they:

   a. Provide record of current Radiological Worker I or II standardized core training
   b. Receive site-specific Radiological Worker I or II training at the facilities where they will be working
   c. Provide their radiation dose records for previous years and written estimates, signed by the individual, for the current year.

3. Proposed use of the Planned Special Exposure as specified in 10 CFR 835 shall be applied only in extraordinary situations and when the following requirements have been met:

   a. The proposed activity has been reviewed by the Radiological Control Manager and submitted by the senior site executive to the lead Secretarial Officer for approval
   b. The proposed activity has been jointly approved by the Secretarial Officer and the Assistant Secretary for Environment, Safety and Health.

4. Emergency exposure limits are not Planned Special Exposure limits. Guidelines for emergency exposures are provided in Appendix 2A.

5. The radiological worker dose limits provided in Table 2-1 also apply to general employees. However, general employees who have not completed Radiological Worker I or II Training are not permitted unescorted access to any area in which they are expected to receive doses in excess of 100 mrem in one year. General employees who have not received Radiological Worker I or II training are not normally expected to exceed 100 mrem in a year.

Table 2-1 Summary of Dose Limits

Exposures shall be well below the limits in this table and maintained as low as reasonably achievable. The Administrative Control Levels for limiting exposure are described in Article 211.

TYPE OF EXPOSURE		ANNUAL LIMIT
Radiological Worker*:	Whole Body (internal + external)	5 rem
Radiological Worker*:	Lens of Eye	15 rem
Radiological Worker*:	Extremity (hands and arms below the elbow; feet and legs below the knees)	50 rem
Radiological Worker*:	Any organ or tissue (other than lens of eye) and skin	50 rem
Declared Pregnant Worker:	Embryo/Fetus	0.5 rem per gestation period
Minors and Students: (under age 18)	Whole Body (internal + external)	0.1 rem
Visitors** and Public:	Whole Body (internal + external)	0.1 rem

* Radiological Workers are General Employees authorized unescorted access to radiological areas per Articles 332, 334, and 335.

** Applies to visitors who have not completed training in accordance with Articles 632 or 633 or have not met the special considerations of Article 657.

Notes:

1. Internal dose to the whole body shall be calculated as committed effective dose equivalent. The committed effective dose equivalent is the resulting dose committed to the whole body from internally deposited radionuclides over a 50-year period after intake. See Appendix 2B for the weighting factors to be used in converting organ dose equivalent to effective dose equivalent for the whole body dose.

2. The annual limit of exposure to "any organ or tissue" is based on the committed dose to that organ or tissue resulting from internally deposited radionuclides over a 50-year period after intake plus any external effective dose equivalent to that organ during the year.

3. Exposure due to background radiation, therapeutic and diagnostic medical procedures, and voluntary participation in medical research programs shall not be included in either personnel radiation dose records or assessment of dose against the limits in this table.

4. See Appendix 2C for guidance on non-uniform exposure of the skin.

214 Visitor Dose Limit

Visitors to DOE sites shall be limited to an annual radiation dose of 100 mrem from the sum of internal and external radiation sources unless they either qualify as radiological workers in accordance with Article 632 or 633, or meet the special considerations of Article 657.

215 Embryo/Fetus Dose Limits

After a female worker voluntarily notifies her employer in writing that she is pregnant, for the purposes of fetal/embryo dose protection, she is considered a declared pregnant worker. This declaration may be revoked, in writing, at any time by the declared pregnant worker.

1. The employer shall provide the option of a mutually agreeable assignment of work tasks, without loss of pay or promotional opportunity, such that further occupational radiation exposure is unlikely.

2. For a declared pregnant worker who chooses to continue working as a radiological worker:

   a. The dose limit for the embryo/fetus from conception to birth (entire gestation period) is 500 mrem
   b. Measures shall be taken to avoid substantial variation above the uniform exposure rate necessary to meet the 500 mrem limit for the gestation period. Efforts should be made to avoid exceeding 50 mrem per month to the declared pregnant worker.

3. If the dose to the embryo/fetus is determined to have already exceeded 500 mrem when a worker notifies her employer of her pregnancy, the worker shall not be assigned to tasks where additional occupational radiation exposure is likely during the remainder of the gestation period.

216 Special Control Levels

Certain situations require lower individualized exposure control levels. In addition to considering recommendations from senior radiological control and medical officials, the contractor senior site executive should obtain advice from professionals in other disciplines such as human resources and legal in establishing Special Control Levels. The contractor senior site executive may wish to establish these Special Control Levels using a radiological health advisory group.

1. A Special Control Level for annual occupational exposure shall be established for each monitored person with a lifetime occupational dose exceeding N rem, where N is the age of the person in years. The Special Control Level shall not exceed 1 rem and should allow the person's lifetime occupational dose to approach N rem as additional occupational exposure is received.

2. An employer should be attentive to special circumstances of employees, such as those undergoing radiation therapy, and establish Special Control Levels as appropriate.

Appendix 2A

Guidelines for Control of Emergency Exposures

In extremely rare cases, emergency exposure to radiation may be necessary to rescue personnel or to protect major property. Emergency exposures may be authorized in accordance with the provisions contained in 10 CFR 835. These doses are in addition to and accounted for separately from the doses received under the limits in Table 2-1. The dose limits for personnel performing these operations are listed below.

DOSE LIMIT (Total Effective Dose Equivalent)	ACTIVITY PERFORMED	CONDITIONS
5 rems	All	
10 rems	Protecting major property	Only on a voluntary basis where lower dose limit not practicable
25 rems	Lifesaving or protection of large populations	Only on a voluntary basis where lower dose limit not practicable
>25 rems	Lifesaving or protection of large populations	Only on a voluntary basis to personnel fully aware of the risks involved

Notes:

1. The lens of the eye dose limit should be three times the listed values.

2. The shallow dose limit to the skin of the whole body and the extremities is ten times the listed values.

PART 3 Posting

231 Posting Requirements

1. Radiological posting shall be used to alert personnel to the presence of radiation and radioactive materials and to aid them in minimizing exposures and preventing the spread of contamination. Boundaries used for radiological control purposes are depicted in Figure 2-1.

2. Signs shall contain the standard radiation symbol colored magenta or black on a yellow background. Lettering shall be either magenta or black. Magenta is the preferred color over black. Standardized signs, as described in the standardized core training, shall be used where practicable.

3. Signs shall be conspicuously posted, clearly worded, and, where appropriate, may include radiological control instructions. Radiological postings should be displayed only to signify actual or potential radiological conditions. Signs used for training should be clearly marked, such as "For Training Purposes Only."

4. Posted areas should be as small as practicable for efficiency.

5. Postings should be maintained in a legible condition and updated based upon the results of the most recent surveys.

6. If more than one radiological condition (such as contamination and high radiation) exists in the same area, each condition should be identified.

7. In areas of ongoing work activities, the dose rate and contamination level or range of each should be included on or in conjunction with each posting as applicable.

8. Entrance points to areas of ongoing work activities controlled for radiological purposes should state basic entry requirements, such as dosimetry, Radiological Work Permit (RWP) and respirator required.

9. Rope, tape, chain and similar barriers used to designate the boundaries of posted areas should be yellow and magenta in color.

10. Physical barriers should be placed so that they are clearly visible from all directions and at various elevations. They should not be easily walked over or under, except at identified access points. These barriers shall be set up such that they do not impede the intended use of emergency exits or evacuation routes.

11. Posting of doors should be such that the postings remain visible when doors are open or closed.

12. A radiological posting that signifies the presence of an intermittent radiological condition should include a statement specifying when the radiation is present, such as "CAUTION: RADIATION AREA WHEN RED LIGHT IS ON."

232 Posting Controlled Areas

1. Each access point to a Controlled Area shall be posted, identifying it as a Controlled Area, whenever radioactive materials or radiation fields which would require posting under Articles 234 or 235 (except for Fixed Contamination Areas) may be present in the area. Persons who enter only the Controlled Area without entering Radiation, Contamination, Airborne Radioactivity or Radiological Buffer Areas are not expected to receive more than 100 mrem in a year.

2. The contractor may select the type of sign used to avoid conflict with local security requirements. This selection shall be approved by the site senior executive.

233 Posting Radiological Buffer Areas

Radiological Buffer Areas shall be established within the Controlled Area to provide secondary boundaries to minimize the spread of contamination and to limit doses to general employees who have not been trained as radiological workers. It is not expected that Radiological Buffer Areas will be established around inactive or secured Contamination Areas. The need for Radiological Buffer Areas in conjunction with Radioactive Material Areas should be evaluated.

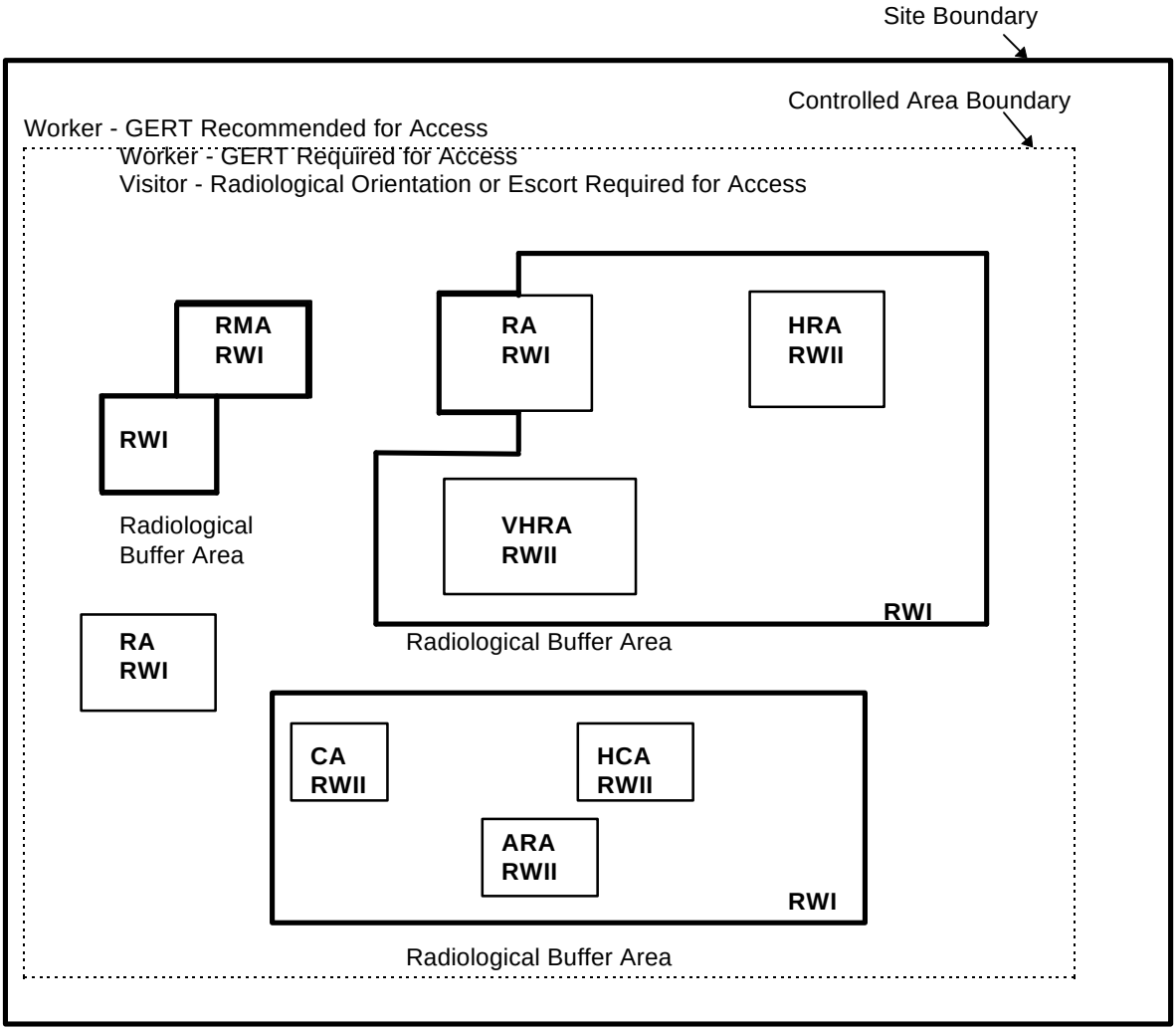
1. The size of the Radiological Buffer Area should be commensurate with the potential for the spread of contamination outside Contamination, High Contamination and Airborne Radioactivity Areas. At a minimum, the Radiological Buffer Area should include the area adjacent to any exit from and entrance to Contamination, High Contamination and Airborne Radioactivity Areas.

2. A Radiological Buffer Area is not required for High Contamination Areas or Airborne Radioactivity Areas that are completely within Contamination Areas.

3. A Radiological Buffer Area established to limit exposure to external radiation should surround Radiation, High Radiation and Very High Radiation Areas. The boundary for the Radiological Buffer Area should be established to limit radiation doses to general employees to less than 100 mrem per year. Radiological Buffer Areas need not be posted for external exposure control if other posted boundaries provide equivalent employee protection.

4. Posting of Radiological Buffer Areas shall be in accordance with Article 231 and shall contain the wording "CAUTION, RADIOLOGICAL BUFFER AREA."

Figure 2-1
Establishing Posted Areas



Legend:

GERT-	General Employee Radiological Training	HRA-	High Radiation Area
RWI-	Radiological Worker I	VHRA-	Very High Radiation Area
RWII-	Radiological Worker II	CA-	Contamination Area
RMA-	Radioactive Material Area	HCA-	High Contamination Area
RA-	Radiation Area	ARA-	Airborne Radioactivity Area

234 Posting Radiation Areas

1. Areas shall be posted to alert personnel to the presence of external radiation in accordance with Table 2-3 and Article 231.

2. Dose rate measurements used to determine criteria for Radiation Areas should be made at a distance of 30 centimeters from the radiation source or from any surface through which the radiation penetrates. For Very High Radiation Areas, the measurement should be made at 100 cm.

3. Contact readings should be used to determine the need for posting Hot Spots. Measures taken to identify sources of elevated general area radiation levels while conducting routine radiation surveys should be sufficient to identify hot spot locations. Special surveys for the sole purpose of identifying hot spots should not be required.

4. A label marking the location of the Hot Spot should be placed on or as near the spot as practical. The provisions of Article 231.7 through 231.11 do not apply to the Hot Spot posting. Posting of Hot Spots is not required in areas with general area dose rates greater than 1 rem/hr.

5. The requirement for personnel dosimetry should be included on the sign.

6. The requirement for an RWP should be included either on or in conjunction with the posting.

7. Dose received in an hour may be used as the criterion for posting (Column 2 of Table 23). In this table, the unit "rad" is associated with dose rates that pose an immediate danger.

Table 2-3 Criteria for Posting Radiation Areas

AREA	DOSE RATE CRITERIA	POSTING
Radiation Area	> 0.005 rem/hr and ≤ 0.1 rem/hr at 30 cm.	"CAUTION, RADIATION AREA" "Personnel Dosimeter Required for Entry"
High Radiation Area	> 0.1 rem/hr at 30 cm and ≤ 500 rad/hr at 100 cm.	"DANGER, HIGH RADIATION AREA" "Personnel Dosimeter, Supplemental Dosimeter and RWP Required for Entry"*
Very High Radiation Area	> 500 rad/hr at 100 cm.	"GRAVE DANGER, VERY HIGH RADIATION AREA" "SPECIAL CONTROLS REQUIRED FOR ENTRY"*
Hot Spot	5 times general area dose rate and > 0.1 rem/hr	"CAUTION, HOT SPOT"

* Access requirements may be deleted or modified if personnel access is specifically prohibited.

235 Posting Contamination, High Contamination and Airborne Radioactivity Areas

1. Areas shall be posted to alert personnel to contamination in accordance with Table 2-4 and Article 231.

2. The requirement for an RWP should be included either on or in conjunction with each posting as applicable.

3. Derived Air Concentration (DAC) values for use with Table 2-4 are found in 10 CFR 835.

4. Areas meeting the criteria for Fixed Contamination Areas specified in Table 2-4 and Article 222.3 do not have to be posted as Contamination or High Contamination Areas.

Table 2-4 Criteria for Posting Contamination, High Contamination and Airborne Radioactivity Areas

AREA	CRITERIA	POSTING
Contamination	Contamination levels (dpm/100 cm^2) > 1 time but ≤ 100 times Table 2-2 values	"CAUTION, CONTAMINATION AREA"
High Contamination	Contamination levels (dpm/100 cm^2) > 100 times Table 2-2 values	"DANGER, HIGH CONTAMINATION AREA" "RWP Required for Entry"
Fixed Contamination	Removable contamination levels < Table 2-2 removable values and total contamination levels > Table 2-2 total values	"CAUTION, FIXED CONTAMINATION"
Soil Contamination	Contaminated soil not releasable in accordance with DOE 5400.5	"CAUTION, SOIL CONTAMINATION AREA"
Airborne Radioactivity	Concentrations (µCi/cc) > 10% of any DAC value	"CAUTION, AIRBORNE RADIOACTIVITY AREA" "RWP Required for Entry"

236 Posting Radioactive Material Areas

1. Areas where radioactive materials are used, handled or stored should be posted"CAUTION, RADIOACTIVE MATERIAL." The posting shall meet the requirements in Article 231.

2. Radioactive Material Areas should be located within Controlled Areas.

3. Radioactive Material Areas are not required when the radioactive material in any one location:

   a. Consists of ten or less sealed sources with half-lives less than 30 days or activities less than those specified in Table 1 of DOE N 5400.9 (Extended by DOE N 5400.10)

   b. Is inside a Contamination, High Contamination, or Airborne Radioactivity Area.

4. The definition of radioactive material and the requirements for labeling radioactive material are contained in Chapter 4.

237 Posting Underground Radioactive Material Areas

1. Underground Radioactive Material Areas shall be established to indicate the presence of underground items that contain radioactive materials such as pipelines, radioactive cribs, covered ponds, covered ditches, catch tanks, inactive burial grounds, and sites of known, covered, unplanned releases (spills).

2. Underground Radioactive Material Areas shall be posted "UNDERGROUND RADIOACTIVE MATERIAL." Posting should include instructions or special warnings to workers such as "Consult With Radiological Control Organization Before Digging" or "Subsurface Contamination Exists." The posting shall meet the applicable requirements of Article 231.

3. Underground Radioactive Material Areas may be located outside Controlled Areas unless access is likely to result in individual doses greater than 100 mrem/year in a year from underground radioactive material.

4. Underground Radioactive Material Areas are exempt from the entry and exit requirements of Chapter 3 when access is not likely to result in individual doses greater than 100 mrem in a year. When access is likely to result in individual doses greater than 100 mrem in a year, entry requirements in Article 332.1 should be implemented.

Endnotes/References:

[1] Rocky Flats Environmental Technology Site*, Radiological Worker II Training Self Study Guide, Revision 0*, (Golden, CO: EG&G Rocky Flats, Inc., 1994)
[2] James E. Turner, *Atoms, Radiation, and Radiation Protection*, (Elmsford, NY: Pergamon Press Inc., 1986), ISBN: 0-08-031949-1.
[3] U.S. Department of Energy, *DOE-HDBK-1019/1-93, DOE Fundamentals Handbook, Nuclear Physics and Reactor Theory, Module 1, Atomic and Nuclear Physics*, (Oak Ridge, TN: Office of Scientific and Technical Information, 1993).
[4] Michael R. Lindeburg, P.E., *Engineer in Training Reference Manual, 8th Edition,* (Belmont, CA: Professional Publications, Inc., 1992), ISBN: 0-912045-56-6.
[5] General Electric Company, Nuclear Energy Operations*, Nuclides and Isotopes, Chart of the Nuclides, 14th Edition,* (San Jose, CA: General Electric Company, 1989).
[6] Rocky Flats Environmental Technology Site*, Radiological Operating Instructions, Section 3*, (Golden, CO: EG&G Rocky Flats, Inc., 1995).
[7] U.S. Department of Energy, *Radiological Control Manual, DOE/EH-0256T Revision 1*, (Washington, DC: DOE, 1994)
[8] Rocky Flats Environmental Technology Site, *Rocky Flats Shift Manager/STA Operations Training, Fundamentals Phase II, 202: Radiation Instrumentation, Rev. 0*, (Golden, CO: EG&G Rocky Flats, Inc., 1990).
[9] *10 CFR Part 835, Occupational Radiation Protection; Final Rule*, December 14, 1993.

SECTION 3: ENVIRONMENTAL MANAGEMENT

3.1 Personnel shall demonstrate knowledge of DOE/Federal orders, standards, and regulations related to environmental protection, restoration, and waste management issues.

a. Discuss the purpose of the following environmental regulations as they apply to the Department and Management & Oversight Contractors:

National Environmental Policy Act (NEPA) The Act establishes national environmental policy and goals for the protection, maintenance, and enhancement of the environment and it provides a process for implementing these goals within the federal agencies. Section 102 requires federal agencies to incorporate environmental considerations in their planning and decision-making through a systematic interdisciplinary approach. Specifically, all federal agencies are to prepare detailed statements assessing the environmental impact of and alternatives to major federal actions significantly affecting the environment. These statements are commonly referred to as environmental impact statements (EISs).

National Pollution Discharge Elimination System (NPDES) The NPDES program is an element of the Clean Water Act (CWA) designed to impose effluent limitations on, or otherwise to prevent, discharges of "pollutants" into any "waters of the United States" from any "point source". The NPDES is a permit program requiring dischargers to disclose the volume and nature of their discharges, authorizing EPA or the states to specify the limitations to be imposed on such discharges, imposing on dischargers an obligation to monitor and report as to their compliance or noncompliance with limitations so imposed, and authorizing EPA or state and citizen enforcement in the event of non-compliance.

Occupational Safety and Health Act (OSHA) The law was enacted in 1970 in an effort to reduce workplace injuries and illnesses by establishing standards that would enhance safe and healthful working conditions in places of employment throughout the United States. The declared congressional purpose and policy of the act is "to assure so far as possible every working man and woman in the nation safe and healthful working conditions and to preserve our human resources." (Section 2(b), 29 USC 651(b)).

Resource Conservation and Recovery Act (RCRA) RCRA is a regulatory statute designed to provide "cradle to grave" control of hazardous waste by imposing management requirements on generators

and transporters of hazardous wastes and upon owners and operators of treatment, storage and disposal (TSD) facilities. RCRA applies mainly to active facilities, and does not address the serious problem of abandoned and inactive sites. RCRA amended the Solid Waste Disposal Act (SWDA) therefore the two terms are sometimes used synonymously.

Subtitle A of RCRA declares that, as a matter of national policy, the generation of hazardous waste is to be reduced or eliminated as expeditiously as possible, and land disposal should be the least favored method for managing hazardous wastes. In addition, all waste that is generated must be handled so as to minimize the present and future threat to human health and the environment.

Comprehensive Environmental Response, Compensation, and Liability Act - Superfund Act (CERCLA) In 1980, Congress enacted the Comprehensive Environmental Response, Compensation, and Liability Act, usually referred to as "CERCLA" or "Superfund". CERCLA's most basic purposes are to provide funding and enforcement authority for cleaning up the thousands of hazardous "waste sites" created in the U.S. in the past which are now abandoned and inactive and to respond to hazardous substance spills.

b. Using references, discuss the purpose of the following environmental regulations as they apply to the Department and Management & Oversight Contractors:

Asbestos Hazard Emergency Response Act (AHERA) Congress amended the Toxic Substances Control Act (TSCA) in 1986 by adding Title III, The Asbestos Hazard Emergency Response Act (AHERA). AHERA requires the EPA to establish a comprehensive regulatory framework of inspection, management, planning, operations and maintenance activities, and appropriate abatement responses for controlling asbestos-containing materials in schools. AHERA also required the EPA to conduct a study to determine the extent of danger to human health posed by asbestos in public and commercial buildings and the means to respond to such danger. Based on the study, EPA did not recommend a regulatory program modeled on AHERA for public and commercial buildings.

Atomic Energy Act There are two Atomic Energy Acts: 1946 and 1954. The Atomic Energy Act of 1946 established the Atomic Energy Commission (AEC) to administer atomic energy materials and to pursue research, production, and development programs. The 1946 Act required that the federal government retain ownership of all fissionable materials

and related production facilities. The legislation did not grant exclusive federal authority over the ownership of "source materials," which are defined as uranium, thorium, and ores containing these substances in concentrations established by the Commission. Nevertheless, the 1946 Act gave the Commission the power to control the possession and transfer of source materials.

The Atomic Energy Act of 1954 established a comprehensive program of licensing and regulation by the federal government. The 1954 legislation authorized the Commission to license the construction and operation of facilities that produce and use special nuclear material.

Clean Water Act (CWA) The CWA was enacted to improve the quality of surface water. The CWA is comprised of the following five elements: 1) a system of minimum national effluent standards for each industry; 2) water quality standards; 3) a discharge permit program where these standards are translated into enforceable limitations (i.e., the NPDES program); 4) provisions for special problems such as toxic chemicals and oils spills; and 5) a revolving construction loan program for publicly-owned treatment works.

Clean Air Act (CAA) The purposes of the CAA are: 1) to protect and enhance the quality of the Nation's air resources so as to promote the public health and welfare and the productive capacity of its population; 2) to initiate and accelerate a national research and development program to achieve the prevention and control of air pollution; 3) to provide technical and financial assistance to state and local governments in connection with the development and execution of their air pollution prevention and control programs; and 4) to encourage and assist the development and operation of regional air pollution prevention and control programs.

Emergency Planning and Community Right-To-Know Act (EPCRA) EPCRA was enacted as a freestanding provision of the Superfund Amendments and Reauthorization Act (SARA). EPCRA requires state and local governments to develop emergency plans for responding to unanticipated environmental releases of a number of acutely toxic materials known as "extremely hazardous substances." Additionally, the statute has established an information collection and transfer program. In general, businesses covered by EPCRA are required to notify state and local emergency planning entities of the presence and quantities in inventory of such substances at their facilities and to notify federal, state and local authorities of planned and unplanned environmental releases of those substances.

Federal Facilities Compliance Act (FFCA) The Federal Facilities Compliance Act of 1992 establishes that federal facilities do not have

sovereign immunity from state enforcement of state environmental laws under the solid and hazardous waste provisions of the Solid Waste Disposal Act (SWDA). Thus, federal facilities are obligated to pay fines and penalties assessed by states. Additionally, provisions of the Act give EPA broader enforcement authority at federal facilities. Specific to the Department of Energy, the Act includes a three-year moratorium on enforcement of storage provisions for mixed hazardous and radioactive wastes. The Act created a new mixed waste provision requiring reports on the national inventory of all mixed-waste on a state-by-state basis and on the nation's inventory on mixed waste treatment capacities and technologies. As a result of these reporting requirements RFETS has developed, obtained approval from the state, and committed to compliance with the Site Treatment Plan (STP). The STP addresses technologies and capacities to treat mixed waste to meet the Land Disposal Requirements (LDR).

The Act limits the civil liability of federal employees acting within the scope of their official duties, however increases the potential criminal liability of federal employees.

Federal Insecticide, Fungicide, and Rodenticide Act of 1988 (FIFRA) FIFRA regulates the distribution, sale and use of pesticides. All pesticides used within the U.S. must be registered with the EPA. The registration process includes chemical identification, labeling requirements, and identification of adverse human and environmental effects.

Fish and Wildlife Coordination Act (FWCA) The purpose of the FWCA is two-fold: 1) to recognize "the vital contribution of our wildlife resources to the Nation, the increasing public interest and significance thereof due to expansion of our national economy and other factors", and 2) "to provide that wildlife conservation shall receive equal consideration and be coordinated with other features of water-resource development programs through effectual and harmonious planning, development, maintenance, and coordination of wildlife conservation and rehabilitation."

Hazardous Materials Transportation Act (HMTA) HMTA provides uniform standards to regulate hazardous materials transportation. Individual responsibilities under the HMTA are: recognize materials and know when it is okay for transport/receipt, understand the hazards during movement and respond accordingly if problems arise, ensure the transporter is a qualified carrier for the transportation of hazardous material, and follow and comply with the applicable regulations.

Pollution Prevention Act of 1990 (PPA) The PPA states, "the Congress hereby declares it to be the national policy of the United States that pollution should be prevented or reduced at the source whenever feasible; pollution that cannot be prevented should be recycled in an environmentally safe manner, whenever feasible; pollution that cannot be prevented or recycled should be treated in an environmentally safe manner whenever feasible; and disposal or other release into the environment should be employed only as a last resort and should be conducted in an environmentally safe manner".

Safe Drinking Water Act (SDWA) The SDWA was enacted to regulate drinking water systems. The act required EPA to set national standards for levels of contaminants in drinking water, and created a program for states to regulate underground injection wells and for the protection of sole source aquifers.

Superfund Amendment Reauthorization Act (SARA) In 1986, Congress enacted significant revisions to CERCLA through the SARA. SARA simply made CERCLA bigger and more complex.

Toxic Substance Control Act (TSCA) The TSCA has two main regulatory features: First, acquisition of sufficient information by EPA to identify and evaluate potential hazards from chemical substances; Second, regulation of the production, use, distribution, and disposal of such substances where necessary. The main provisions of the Act include: premanufacture notification (PMN), inventory list (Section 8), reporting requirements, and testing requirements.

Additionally, TSCA specifically regulates polychlorinated biphenyl (PCB), chlorofluorocarbons (CFC), and asbestos.

c. Using references, discuss the purpose of the following DOE Orders as they apply to the Department and Management & Oversight Contractors:

5400.1 - General Environmental Protection Program
Portions of this order have been deleted by DOE Order 231.1, 09-30-95, Environment, Safety, and Health Reporting; other portions have been incorporated into the same order.

NOTE: The objective of the new order is to ensure collection and reporting of information on environment, safety and health that is required by law or regulation to be collected, or that is essential for evaluating Department of Energy (DOE) operations and identifying opportunities for

improvement needed for planning purposes within the DOE.

5400.2A - Environmental Compliance Issue Coordination Canceled per DOE Notice 251.6. Information from this order is now in DOE Order 231.1, 09-30-95, Environment, Safety, and Health Reporting.

NOTE: The objective of the new order is to ensure collection and reporting of information on environment, safety and health that is required by law or regulation to be collected, or that is essential for evaluating Department of Energy (DOE) operations and identifying opportunities for improvement needed for planning purposes within the DOE.

5400.3 - Hazardous and Radioactive Mixed Waste Program
This order was canceled 03-94.

5400.4 - Comprehensive Environmental Response, Compensation, and Liability Act Requirements Canceled per DOE Notice 251.6.

5400.5 - Radiation Protection of the Public and the Environment
Portions of this order have been incorporated into DOE Order 231.1, 09-30-95, Environment, Safety, and Health Reporting.

NOTE: The objective of the new order is to ensure collection and reporting of information on environment, safety, and health that is required by law or regulation to be collected, or that is essential for evaluating Department of Energy (DOE) operations and identifying opportunities for improvement needed for planning purposes within the DOE.

5440.1E - National Environmental Policy Act Canceled per DOE Order 451.1, 09-11-95, NEPA Compliance Program

NOTE: The objective of the new order is to establish DOE internal requirements and responsibilities for implementing the National Environmental Policy Act (NEPA) of 1969, the Council on Environmental Quality Regulations Implementing the Procedural Provisions of the NEPA (40 CFR Parts 1500-1508), and the DOE NEPA Implementing Procedures (10 CFR Part 1021). The goal of establishing the requirements and responsibilities is to ensure efficient and effective implementation of DOE's NEPA responsibilities through teamwork. A key responsibility for all participants is to control the cost and time for the NEPA process while maintaining its quality.

5480.1B - Environment, Safety, and Health Program for the Department of Energy Operations Canceled per DOE Notice 251.4.

5480.4 - Environmental Protection, Safety, and Health Protection Standards Portions of this order were canceled by DOE Order 440.1, 09-30-95, Worker Protection Management for DOE Federal and Contractor Employees, other portions have been incorporated into the same new three digit order.

NOTE: The objective of the order is to establish the framework for an effective worker protection program that will reduce or prevent accidental losses, injuries, and illnesses by providing DOE federal and contractor workers with a safe and healthful workplace.

5482.1B - Environment, Safety, and Health Appraisal Program
The purpose of the order is to establish the Environment, Safety, and Health (ES&H) Appraisal Program for the Department of Energy (DOE).

5484.1 - Environmental Protection, Safety, and Health Protection Information Reporting Requirements
Portions of this order have been deleted by DOE Order 231.1, 09-30-95, Environment, Safety, and Health Reporting, other portions have been incorporated into this same order.

NOTE: The objective of the order is to ensure collection and reporting of information on environment, safety and health that is required by law or regulation to be collected, or that is essential for evaluating Department of Energy (DOE) operations and identifying opportunities for improvement needed for planning purposes within the DOE.

5820.2A - Radioactive Waste Management The purpose of this order is to establish policies, guidelines, and minimum requirements by which the Department of Energy (DOE) manages its radioactive and mixed waste and contaminated facilities.

d. Compare and contrast the associated material classification criteria for the following:

Low Level Radioactive Waste Low Level Radioactive Waste (LLW) is material having no economic value and contaminated with radioactive material that is not classified as high-level waste, transuranic waste*, spent nuclear fuel or byproduct material as defined in Section 11e(2) of the Atomic Energy Act, as amended. Test specimens of fissionable material irradiated only for research and development and not for

production of power or plutonium may be classified as low level waste provided the concentration of transuranic activity (i.e. americium, plutonium, etc.) is less than or equal to 100 nCi per gram.

**Transuranic (TRU) Waste* (referred to above) Radioactive waste material without regard to source or form that, at the end of institutional control periods is contaminated with alpha-emitting radionuclides having atomic numbers greater than 92 (Uranium) and half-lives greater than 20 years in concentrations above 100 nCi per gram of waste matrix at time of assay and are not co-mingled with RCRA constituents.

Transuranic Waste Mixed (TRU-M) Radioactive waste material without regard to source or form that, at the end of institutional control periods is contaminated with alpha-emitting radionuclides having atomic numbers greater than 92 (Uranium) and half-lives greater than 20 years in concentrations above 100 nCi per gram of waste matrix at time of assay and are co-mingled with RCRA constituents.. It is produced primarily from reprocessing spent fuel and from the use of Plutonium in fabrication of nuclear weapons.

High Level Radioactive Waste Material generated by chemical reprocessing of spent fuel and irradiated targets. High-level waste contains highly radioactive, short-lived fission products, hazardous chemicals, and toxic heavy metals. High-level waste is usually found in the forms of a liquid, a solid saltcake, a sludge, or a dry powdery calcine.

Hazardous Waste Those wastes which exhibit the characteristics of being corrosive, ignitable, reactive, toxic, or are listed in 40 CFR 261.

Mixed Hazardous Waste Hazardous waste containing both radioactive and hazardous components as defined by the Atomic Energy Act of 1954 and RCRA respectively.

3.2 Personnel shall demonstrate knowledge of the purpose and general content of the sections of a typical Environmental Impact Statement (EIS).

a. Using a typical Environmental Impact Statement as a reference, discuss the purpose of the sections as they apply to the Department and Management & Oversight Contractors.

The following standard format for environmental impact statements should be followed unless the agency determines that there is a compelling reason to do otherwise: Cover sheet, Summary, Table of

contents, Purpose of and need for action, Alternatives, Affected environment, Environmental consequences, List of preparers, Lists of Agencies, Organizations, and persons to whom copies of the statement are sent, Index, and Appendices.

Summary - The summary shall stress the major conclusions, areas of controversy (including issues raised by agencies and the public), and issues to be resolved (including the choice among alternatives).

Purpose and need - The statement shall briefly specify the underlying purpose and need to which the agency is responding in proposing the alternatives including the proposed action.

Alternatives - This section is the heart of the environmental impact statement. Based on the information and analysis presented in the sections on the Affected Environment and the Environmental Consequences, it should present the environmental impacts of the proposal and the alternatives in comparative form. This section clearly defines the issues and provides a clear basis for choice among options by the decisionmaker and the public. The alternative of no action will be included, and the preferred action or alternatives will be highlighted. Additionally, mitigation measures will be addressed.

Affected environment - The environmental impact statement shall succinctly describe the environment of the area(s) to be affected or created by the alternatives under consideration.

Environmental consequences - This section forms the scientific and analytic basis for the comparisons in the Alternatives section. It shall include discussions of : direct effects and their significance, indirect effects and their significance, and possible conflicts between the proposed action and the objectives of federal, regional, state, and local land use plans, policies and controls for the area concerned, energy requirements and conservation potential of various alternatives and mitigation measures, natural or depletable resource requirements and conservation potential, and urban quality.

List of preparers - The environmental impact statement shall list the names, together with their qualifications, of the persons who were primarily responsible for preparing the environmental impact statement.

b. Using a typical Environmental Impact Statement as a reference, discuss the role of the Department in the generation, review, and approval process associated with an Environmental Impact Statement.

The NEPA Compliance Program is outlined in DOE Order 451.1. This Order defines the management roles and responsibilities in implementing the Council on Environmental Quality Regulations Implementing the Procedural Provisions of NEPA (40 CFR Parts 1500-1508) and the DOE NEPA Implementing Procedures (10 CFR Part 1021). The goal of the Order is to establish requirements and responsibilities to ensure efficient and effective implementation of DOE's NEPA responsibilities through teamwork. The requirements of the Order include: 1) A system of DOE NEPA Compliance Officers; 2) Internal scoping procedures for environmental assessments and environmental impact statements that include development of a schedule. For an environmental impact statement, the schedule will provide for completion of a final environmental impact statement within 15 months of the issuance of the Notice of Intent; 3) NEPA quality assurance plans and public participation plans; 4) Annual NEPA planning summaries; 5) A NEPA Document Manager for each environmental impact statement and environmental assessment; 6) A system for reporting lessons learned and encouraging continuous improvement; and 7) Tracking and annually reporting progress in implementing a commitment for environmental impact mitigation.

The NEPA decision making process has been delegated to the Heads of the Field Organizations. With the assistance of the NEPA Compliance Officer and the NEPA Document Manager the Head of the Field Organization can perform the NEPA process with little or no input from DOE Headquarters.

3.3 Personnel shall demonstrate knowledge of the purpose and content of 29 CFR 1910.120 Hazardous Waste Operations and Emergency Response.

a. Using 29 CFR 1910.120 as a reference, discuss its purpose as it applies to the Department and Management & Oversight Contractors with respect to:

The scope of 29 CFR 1910.120 covers the following operations, unless the employer can demonstrate that the operation does not involve employee exposure or the reasonable possibility for employee exposure to safety or health hazards:

Cleanup Operations The regulations state, "clean-up operations required by a governmental body, whether federal, state, local or other involving hazardous substances that are conducted at uncontrolled

hazardous waste sites (including, but not limited to, the EPA's National Priority Site List (NPL), state priority site lists, sites recommended for the EPA NPL, and initial investigations of government identified sites which are conducted before the presence or absence of hazardous substances has been ascertained)."

The definition "means an operation where hazardous substances are removed, contained, incinerated, neutralized, stabilized, cleared-up, or in any other manner processed or handled with the ultimate goal of making the site safer for people or the environment."

Corrective Actions Corrective actions involve clean-up operations at sites covered by the Resource Conservation Recovery Act (RCRA).

Voluntary Clean-up Operations These are clean-up operations conducted on a voluntary basis at sites determined to be uncontrolled hazardous waste sites.

Operations Involving Hazardous Wastes These are operations involving hazardous wastes that are conducted at treatment, storage, and disposal (TSD) facilities regulated by 40 CFR parts 264 and 265 pursuant to RCRA; or by agencies under agreement with EPA to implement RCRA regulations.

Emergency Response Operations These operations are in response to release of, or substantial threats of releases of, hazardous substances without regard to the location of the hazard. The regulatory definition is "a response effort by employees from outside the immediate release area or by other designated responders (i.e., mutual-aid groups, local fire departments, etc.) to an occurrence which results, or is likely to result, in an uncontrolled release of a hazardous substance."

b. Using 29 CFR 1910.120 as a reference, discuss the role of the Department in the identification, assessment, and reaction to potential risks posed by hazardous wastes that exist at Department sites.

At facilities conducting clean-up operations, RCRA corrective actions, voluntary clean-up operations, treatment, storage or disposal under RCRA, and emergency response operations, 29 CFR 1910.120 requires: 1) a safety and health program; 2) site characterization and analysis; 3) site control; 4) training; 5) medical surveillance; 6) engineering controls, work practices, and personal protective equipment for employee protection; 7) monitoring; 8) informational programs; 9) drum and container handling procedures; 10) decontamination procedures; 11)

emergency response plan; 12) site illumination; 13) sanitation at temporary workplaces; and, 14) new technology programs.

In general, the employers shall develop and implement a written safety and health program for their employees involved in hazardous waste operations. The program shall be designed to identify, evaluate, and control safety and health hazards, and provide for emergency response for hazardous waste operations. The safety and health program is required to provide the following elements: organizational structure, comprehensive workplan, site-specific safety and health plan, safety and health training program, medical surveillance program, and employer's standard operating procedure for safety and health.

3.4 Personnel shall demonstrate knowledge of potential personal and organizational liability associated with the Federal environmental regulations with applicability to Department facility operations.

a. Using references, discuss the Department's liabilities associated with the following environmental regulations as they apply to the Department and Management & Oversight Contractors:

STATUTE	CIVIL LIABILITIES	CRIMINAL LIABILITIES
Asbestos Hazard Emergency Response Act (AHERA)	Up to $5,000 per day for each day of violation	None
Clean Water Act (CWA)	Up to $25,000 per day for each day of violation	Negligent violations: $25,000 per day, or 1 year in prison, or both. Knowing violations: $5,000-$50,000 per day, or 3 years in prison, or both Knowing endangerment: $250,000, or 15 years in prison, or both
Clean Air Act (CAA)	Up to $25,000 per day for each day of violation	Negligent = 1 year Knowing = 5 years + $$ Knowing Endangerment = 15 years + $1M Falsification = 2 years
Comprehensive	Up to $25,000 per day	None

Environmental Response, Compensation, and Liability Act - Superfund Act (CERCLA)	for each day of violation and punitive damages from one to three times the total clean up cost.	

Emergency Planning and Community Right-To-Know Act (EPCRA)	$10,000 - 25,000 per day for each day of violation	$25,000, or 2 years in prison, or both
Hazardous Material Transportation Act (HMTA)	Up to $25,000 per day for each day of violation with a $250 minimum	$500,000 per day for corporations and $250,000 per day for individuals and/or 5 years in prison
National Environmental Policy Act (NEPA)	None	None
National Pollution Discharge Elimination System (NPDES)	See CWA	See CWA
Occupational Safety and Health Act (OSHA)	Up to $70,000 for willful violations. Up to $7,000 per day for each serious violation.	Willful resulting in death =$10,000 = 6 mo in prison.
Pollution Prevention Act of 1990 (PPA)	None (voluntary pgrm)	None (voluntary pgrm)
Resource Conservation Recovery Act (RCRA)	Up to $25,000 per day for each day of violation	$50,000 per day, for each day of violation and/or 5 years in prison Knowing endangerment $250,000 and/or 15 years in prison for an individual and $1,000,000 for a corporation
Safe Drinking Water Act (SDWA)	Up to $25,000 per day for each day of violation	$25,000 per day for each day of violation, and/or 3 years in prison
Superfund Amendment Reauthorization Act (SARA)	See CERCLA	See CERCLA

Toxic Substance Control Act (TSCA)	Up to $25,000 per day, per violation	$25,000 per day for each day of violation, and/or 1 year in prison

3.5 Personnel shall demonstrate knowledge of potential personal and organizational liability associated with the Federal Facilities Compliance Act (FFCA).

a. Using the Federal Facilities Compliance Act as a reference, discuss the Department's liabilities associated with the Federal Facilities Compliance Act including the following:

Federal Agency Liability - Per the FFCA, federal facilities do not have sovereign immunity from state enforcement of state environmental laws under the solid and hazardous waste provisions of the Solid Waste Disposal Act (SWDA). Additionally, federal facilities are obligated to pay fines and penalties assessed by the states.

Federal Employee Liability Federal employees can be personally liable for both civil and criminal penalties imposed under the solid and hazardous waste provisions of the Solid Waste Disposal Act (SWDA).

Civil Penalties The Act exempts personal liability of agents, employees, or officers of the United States for any civil penalty under any federal, state, interstate, or local solid or hazardous waste law with respect to any act or omission **within the scope of the official duties** of the agent, employee, or officer. However, federal agencies are now liable for civil penalties and fines.

Criminal Penalties The Act states, "an agent, employee, or officer of the United States shall be subject to any criminal sanction (including, but not limited to, any fine or imprisonment) under any federal or state solid or hazardous waste law, but no department, agency, or instrumentality of the executive, legislative, or judicial branch of the Federal Government shall be subject to any such sanction".

Resources Conservation and Recovery Act (RCRA) The FFCA amends RCRA to waive the sovereign immunity previously afforded to federal facilities. Federal facilities are now subject to the federal, state, interstate, and local substantive and procedural requirements of the Resource Conservation Recovery Act.

References:

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3. U.S. Department of Energy*, Radiological Control Manual, DOE/EH-0256T Revision 1,* (Washington, DC: DOE, 1994).
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SECTION 4: QUALITY ASSURANCE

4.1 Personnel shall demonstrate the knowledge of Quality Assurance principles necessary to assure safe, effective and efficient operation of DOE sites and associated facilities.

a. Referring to DOE Order 5700.6C, Quality Assurance, discuss the purpose and key features of the ten criteria to be used in developing Quality Assurance Programs.

These ten criteria are divided into three areas: management (4), performance (4) and assessment (2).

The management criteria regard program development such as planning and scheduling, training of staff, the determination of the processes used to check the quality of work, and the establishment of a baseline against which work is compared.

The performance criteria regard doing work and checking products in accordance with established requirements, designing requirements appropriately, and checking that procured items or services comply with established requirements.

The assessment criteria regard the performance of self evaluations and independent evaluations of the quality assurance program.

The purpose and key features of these ten criteria are discussed below.

1) Management—Program

The purpose of this criteria is to broadly outline the content of a quality assurance program. Key features include:

- policy,
- responsibility and authority of staff,
- vocabulary,
- planning,
- program coordination among different organizational or functional areas,
- the need for project pre-start readiness reviews,
- the program should not significantly impair work efficiency or progress,
- the level of quality assurance should be consistent with the risk posed by errors.

2) Management—Personnel Training and Qualification

The purpose of this criteria is to highlight the importance of training to ensure the quality of work. Key features include:

- establishing and implementing qualifications for specific positions,
- staff should be qualified prior to performing work,
- qualification should include a demonstration of proficiency,
- training should instill the value of doing work right the first time,

- training plans should go beyond attainment of initial qualification to include professional development and progressive enhancement of proficiency,
- training should be subject to on-going review of effectiveness to identify areas needing improvement or enhancement.

3) Management—Quality Improvement

The purpose of this criteria is to exemplify the types of processes used to assure or improve quality. Key features are inherent in processes that:

- prevent problems,
- improve quality,
- identify trends that impact quality (positively and negatively),
- raise performance standards and measures (continuous improvement),
- encourage staff to suggest improvements,
- resolve problems and causes commensurate with their significance,
- demonstrate management support and involvement,
- control defective items to prevent inadvertent reuse, and document their disposition (such as repair and retesting, or disposal).

Examples of processes include: peer reviews, design reviews, probabilistic risk assessments, safety analysis reports, reliability analyses, process variability analyses, failure rate reviews, decreasing corrective maintenance, increasing preventative maintenance resources.

4) Management—Documents and Records

Documents are baseline specifications. Records reveal how the work was done and measured. The purpose of this criteria is to emphasize the role of these types of materials in quality assurance. Key features include:

- An overall document control system should be established to control preparation, revision, review and approval, and distribution of active and superseded or canceled documents.
- Types of relevant documents are those that establish policies, prescribe work, specify requirements, or establish design.
- An overall records control system should be established to ensure preparation, review and approval, and maintenance of active records. The system should ensure that the records are auditable and equipment is available to review records (such as computer disks).
- Types of relevant records are those that accurately reflect completed work.
- Record storage and disposition should comply with DOE Order 1324.5B *Records Management Program*.

5) Performance—Work Processes

The purpose of this criteria is to ensure that work is conducted consistently, and that items and equipment are functioning properly through compliance with established work procedures, item and equipment control, and maintenance. Key features include:

- workers are responsible for quality, and for following instructions, procedures and directions to meet defined acceptance criteria,
- line managers are responsible for ensuring that procedures are valid, and to verify that work meets the acceptance criteria,
- needed items and equipment should be identifiable, controlled, calibrated and maintained to ensure traceability, and proper use and storage to preserve the integrity of the item or equipment.

6) Performance—Design

The purpose of this criteria is to ensure that design work is done right the first time. Key features include:

- design work is done according to sound principles and standards,
- changes to designs are justified as meeting the applicable design criteria and properly recorded,
- coordination of design work among different groups is to be done according to established responsibilities and procedures,
- records of how the design work was done are created and maintained,
- acceptability of design bases and design outputs are verified by qualified outside staff,
- design testing demonstrates acceptable performance,
- verification of design outputs is completed prior to relying on the item to perform its function.

Examples of design verification are design reviews, alternate calculations and qualification testing.

7) Performance—Procurement

The purpose of this criteria is to ensure that procured items and services meet requirements (performance, technical, administrative). Key features include:

- evaluate supplier's qualifications,
- establish acceptance criteria for procured items and services,
- the frequency of inspecting procured items and services is set and based on the complexity, significance of errors, quantity and frequency of purchase,
- procurement inspection and test requirements are satisfied prior to using the procured items and services,
- procurement effectiveness is periodically reviewed for possible recalibration.

Examples of methods used to evaluate items and services include: reviewing the manufacturing process control data, source verifications, receipt inspection, pre-installation and post-installation tests and certifications of conformance.

8) Performance—Inspection and Acceptance Testing

The purpose of this criteria is to highlight the role of process inspections and product testing in a quality assurance program.
Key features include:

- inspection plans that specify inspection frequency, what is to be inspected, acceptance criteria and responsibilities of organizations,
- the degree of inspection scrutiny is based on the complexity and the significance of errors and the end use of the product(s),
- product testing is used to demonstrate functionality to the intended performance requirements,
- product designers provide or approve the test requirements and acceptance criteria,
- appropriate resolution of deficiencies,
- staff do not inspect or test their own work for acceptance,
- measuring and testing equipment is defined, identified, labeled, controlled and calibrated at specified intervals.

Examples of tests include bench and proof tests before installation, pre-operational tests, post-maintenance tests, post-modification tests and operational tests.

9) Assessment—Management Assessment

The purpose of this criteria is to review an organization's responsibility to conduct self assessments on it's performance toward meeting quality assurance objectives. Key features include:

- senior management is responsible to ensure these assessments are conducted and to involve all other levels of management as needed,
- focus is on management problems that act as hindrances to achieving objectives,
- documentation is made of assessment results, management decisions and actions, and follow-up on action effectiveness.

10) Assessment—Independent Assessment

The purpose of this criteria is to review an organization's responsibility to request independent assessments on its performance toward meeting quality assurance objectives.
Key features include:

- reviews are to promote improvement in the quality of the processes that lead to end products,
- priority of reviews is based on the status, complexity and significance of errors in the subject area, and on areas of questionable performance,
- problems are tracked to resolution,
- responses may include improvement actions, lessons learned, and actions taken to correct deficiencies, causes and prevent recurrence.

Examples of independent assessment activities include: monitor work performance, identify abnormal performance and precursors of potential problems, identify opportunities for improvement, report results to a level of management having the authority to effect corrective action, and verify satisfactory resolution of problems.

b. Referring to NQA-1, Nuclear Quality Assurance, discuss the purpose of the eighteen (18) basic quality assurance requirements.

This standard sets forth 18 basic requirements for the establishment and execution of quality assurance programs for the siting, design, construction, operation and decommissioning of nuclear facilities.

All of these 18 requirements are duplicative with the 10 criteria discussed above in Section 4.1, a. on DOE Order 5700.6C *Quality Assurance*. Neither reference addresses unique topics not covered by the other. Variations in wording and emphasis exist. Both references have additional clarifying material such as supplements or implementation guides.

The purpose of each of these 18 basic requirements are summarized below.

1) Organization

The organizational structure, functional responsibilities, levels of authority, and lines of communication for activities affecting quality shall be documented. Persons or organizations responsible for assuring that an appropriate quality assurance program has been established and verifying that activities affecting quality have been correctly performed shall have sufficient authority, access to work areas, and organizational freedom to:
(1) identify quality problems;
(2) initiate, recommend, or provide solutions to quality problems through designated channels;
(3) verify implementation of solutions; and
(4) assure that further processing, delivery, installation, or use is controlled until proper disposition of a nonconformance, deficiency, or unsatisfactory condition has occurred.

Such persons or organizations shall have direct access to responsible management at a level where appropriate action can be effected. Such persons or organizations shall report to a management level such that required authority and organizational freedom are provided, including sufficient independence from cost and schedule considerations.

2) Quality Assurance Program

A documented quality assurance program shall be planned, implemented, and maintained in accordance with this Standard, or portions thereof. The program shall identify the activities and items to which it applies. The establishment of the program shall include consideration of the technical aspects of the activities affecting quality. The program shall provide control over activities affecting quality to an extent consistent with their importance. The program shall be established at the earliest time consistent with the schedule for accomplishing the activities.

The program shall provide for the planning and accomplishment of activities affecting quality under suitably controlled conditions. Controlled conditions include the use of appropriate equipment, suitable environmental conditions for accomplishing the activity, and assurance that prerequisites for the given activity have been satisfied. The program shall provide for any special controls, processes, test equipment, tools, and skills to attain the required quality and for verification of quality.

The program shall provide for indoctrination and training, as necessary, of personnel performing activities affecting quality to assure that suitable proficiency is achieved and maintained.

Management of those organizations implementing the quality assurance program, or portions thereof, shall regularly assess the adequacy of that part of the program for which they are responsible and shall assure its effective implementation.

3) Design Control

The design shall be defined, controlled, and verified. Applicable design inputs shall be appropriately specified on a timely basis and correctly translated into design documents. Design interfaces shall be identified and controlled. Design adequacy shall be verified by persons other than those who designed the item. Design changes, including field changes, shall be governed by control measures commensurate with those applied to the original design.

4) Procurement Document Control

Applicable design bases and other requirements necessary to assure adequate quality shall be included or referenced in documents for procurement of items and services. To the extent necessary, procurement documents shall require suppliers to have a quality assurance program consistent with the applicable requirements of this standard.

5) Instruction, Procedures, and Drawings

Activities affecting quality shall be prescribed by and performed in accordance with documented instruction, procedures, or drawings or a type appropriate to the circumstances. These documents shall include or reference appropriate quantitative or qualitative acceptance criteria for determining that prescribed activities have been satisfactorily accomplished.

6) Document Control

The preparation, issue, and change of documents that specify quality requirements or prescribe activities affecting quality shall be controlled to assure that correct documents are being employed. Such documents, including changes thereto, shall be reviewed for adequacy and approved for release by authorized personnel.

7) Control of Purchased Items and Services

The procurement of items and services shall be controlled to assure conformance with specified requirements. Such control shall provide for the following as appropriate: source evaluation and selection, evaluation of objective evidence of quality furnished by the supplier, source inspection, audit, and examination of items or services upon delivery or completion.

8) Identification and Control of Items

Controls shall be established to assure that only correct and accepted items are used or installed. Identification shall be maintained on the items or in documents traceable to the items, or in a manner which assures that identification is established and maintained.

9) Control of Processes

Processes affecting quality of items or services shall be controlled. Special processes that control or verify quality, such as those used in welding, heat treating, and nondestructive examination, shall be performed by qualified personnel using qualified procedures in accordance with specified requirements.

10) Inspection

Inspections required to verify conformance of an item or activity to specified requirements shall be planned and executed. Characteristics to be inspected and inspection methods to be employed shall be specified. Inspection results shall be documented. Inspection for acceptance shall be performed by persons other than those who performed or directly supervised the work being inspected.

11) Test Control

Tests required to verify conformance of an item or computer program to specified requirements and to demonstrate satisfactory performance for services shall be planned and executed. Characteristics to be tested and test methods to be employed shall be specified. Test results shall be documented and their conformance with acceptance criteria shall be evaluated. Tests required to collect data, such as for siting or design input, shall be planned, executed, documented, and evaluated.

12) Control of Measuring and Test Equipment

Tools, gages, instruments, and other measuring and test equipment used for activities affecting quality shall be controlled and at specified periods calibrated and adjusted to maintain accuracy within applicable limits.

13) Handling, Storage, and Shipping

Handling, storage, cleaning, packaging, shipping, and preservation of items shall be controlled to prevent damage or loss and to minimize deterioration.

14) Inspection, Test and Operating Status

The status of inspection and test activities shall be identified either on the items or in documents traceable to the items where it is necessary to assure that required inspections and tests are performed and to assure that items which have not passed the required inspections and tests are not inadvertently installed, used, or operated. Status shall be maintained through indicators, such as physical location and tags, markings, shop travelers, stamps, inspection records, or other suitable means. The authority for application and removal of tags, markings, labels, and stamps shall be specified. Status indicators shall also provide for indicating the operating status of systems and components of the nuclear facility, such as by tagging valves and switches, to prevent inadvertent operation.

15) Control of Nonconforming Items

Items that do not conform to specified requirements shall be controlled to prevent inadvertent installation or use. Controls shall provide for identification, documentation, evaluation, segregation when practical, and disposition of nonconforming items, and for notification to affected organizations.

16) Corrective Action

Conditions adverse to quality shall be identified promptly and corrected as soon as practical. In the case of a significant condition adverse to quality, the cause of the condition shall be determined and corrective action taken to preclude recurrence. The identification, cause, and corrective action for significant conditions adverse to quality shall be documented and reported to appropriate levels of management. Follow-up action shall be taken to verify implementation of this corrective action.

17) Quality Assurance Records

Records that furnish documentary evidence of quality shall be specified, prepared, and maintained. Records shall be legible, identifiable, and retrievable. Records shall be protected against damage, deterioration, or loss. Requirements and responsibilities for record transmittal, distribution, retention, maintenance, and disposition shall be established and documented.

18) Audits

Planned and scheduled audits shall be performed by appropriately qualified personnel to verify compliance with all aspects of the quality assurance program and to determine its effectiveness. These audits shall be performed in

accordance with written procedures or checklists by personnel who do not have direct responsibility for performing the activities being audited. Audit results shall be documented and reported to and reviewed by responsible management. Follow-up action shall be taken where indicated.

c. Discuss the essential elements of a Quality Assurance Plan.

This section of the study guide is based on two U.S. EPA references regarding program plans and project plans. This terminology is comparable to the U.S. DOE terms for program documentation discussed above in Section 4.1, a. and 4.1, b. regarding management, performance and assessment criteria.

The two U.S. EPA references are QAMS-004 *Guidelines and Specifications for Preparing Quality Assurance Program Plans*, and QAMS-005 *Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans*. QAMS stands for the U.S. EPA Quality Assurance Management Staff.

The distinction between program plans and project plans

A quality assurance program plan applies to a larger-sized organization and is intended to be all encompassing. It includes the overall policies, principles, objectives and functional responsibilities designed to achieve data quality goals for the activities for which the particular organization is responsible.

A quality assurance project plan applies to individual projects or to a group of projects that rely on the same work methods. It includes the specific procedures by which a group delineates how it produces quality data for a specific project or work method.

For example, an organization would have one quality assurance manual, but would have a quality assurance plan for each of its projects.

Plan Elements

QAMS-004 lists 11 elements for quality assurance **program** plans.

1) Identification of Program

This provides administrative information such as the document title and number, name and address of the organization, responsible official and approval signatures.

2) Introduction

This describes the background, purpose and scope of the program.

3) Quality Assurance Policy Statement

This section describes the organization's goals, and requirements and activities needed to realize these goals. An example is to use and provide data of known quality by accompanying all data with calculations of precision and accuracy. The policy statement includes management's commitment of time and resources to the program.

4) Quality Assurance Management

This section presents the management structure of the organization showing interrelationships between functional groups which generate or manage data. This section identifies responsibilities of various groups, formal lines of communication within the organization, the document control procedure, and the organization's self assessment process.

5) Personnel Qualifications

Personnel training and qualification needs are identified, and all personnel have the education, training and experience required for their positions.

6) Facilities, Equipment and Services

This section describes the unit's approach to select, evaluate and maintain equipment, facilities and services. This section includes the monitoring and inspection procedures for maintaining equipment, facilities and services. Examples include temperature, humidity, voltage control, reagent purity, supply of air and water, refrigerators, incubators, glove boxes.

7) Data Generation

This section describes procedures to assure the generation of reliable data through the use of quality assurance project plans and standard operating procedures. This section identifies the types of monitoring and measurement activities for which detailed project plans must be developed. Project plans are also to be written for each specific project or continuing operation.

Project plans should provide for the review of all activities which could directly or indirectly influence data quality and the determination of those operations which must be covered by standard operating procedures.

Standard operating procedures should be developed and used to implement routine quality control requirements for all monitoring programs, repetitive tests and measurements and for inspection and maintenance of facilities, equipment and services.

8) Data Processing

This section summarizes how all aspects of data processing will be managed and separately evaluated in order to characterize and maintain the integrity and quality of the data. Data processing includes collection, validation, storage, transfer and reduction.

9) Data Quality Assessment

Quality assurance program plans must describe how all data generated will be assessed for accuracy, precision, completeness, representativeness and comparability. The plan must require that data be accompanied by a calculation of precision and accuracy. Where appropriate, a statement on the completeness, representativeness and comparability also should be included.

10) Corrective Action

This section identifies the need for feedback channels to ensure that early and effective corrective actions can be taken when data quality falls below required limits. It describes mechanisms for corrective actions, when actions are required, who is responsible for implementing actions, verifying their completion and evaluating effectiveness.

11) Implementation Requirements and Schedules

The quality assurance program plan must be accompanied by an implementation schedule.

QAMS-005 lists 16 elements for quality assurance **project** plans.

1) Title Page

This includes approval signatures.

2) Table of Contents

This is self explanatory.

3) Project Description

This is a brief, general description of the project and may include the design, flow diagrams, tables and charts as applicable.

4) Project Organization and Responsibility

This provides an organizational chart of the groups involved in the project, and identifies individual and group responsibilities.

5) Quality Assurance Objectives for Measurement of Data in Terms of Precision, Accuracy, Completeness, Representativeness and Comparability

For each applicable parameter, this section lists the objectives for accuracy, precision and completeness. Data quality objectives are based on the requirements of the specific project, and on prior knowledge of the measurement system employed and method validation studies using replicates, spikes, standards, calibrations and recovery studies.

6) Sampling Procedures

For each applicable parameter, this section describes the sampling procedures to be used. Typical information addressed includes selection of sampling sites, the specific sampling procedure followed, how the sample was collected, special considerations for preparation of sampling equipment and containers, sample preservation, holding and transportation time.

7) Sample Custody

This part of the project plan describes the chain of custody procedures to follow in the field and laboratory. Typical information addressed includes sample labeling, preservation, tracking, recording where it was taken, supplies used in taking the sample (e.g. filters, absorbing reagents), analytical tests and results performed, and responsible individuals at each stage in the process.

8) Calibration Procedures and Frequency

For each applicable parameter, this section provides a description of the calibration procedures or standard operating procedures to be followed. This section includes recalibration frequency and standards.

9) Analytical Procedures

For each applicable parameter, this section provides a description of the analytical procedures or standard operating procedures to be followed.

10) Data Reduction, Validation and Reporting

For each applicable parameter, this section describes the data reduction scheme (i.e., equations and calculations), criteria used to validate data integrity, identification and treatment of outliers, the reporting scheme (from data collection to storage), and key individuals.

11) Internal Quality Control Checks

Here is listed all internal quality control methods to be followed in the project. Examples include replicates, spiked samples, split sample, controls, blanks, internal standards, zero and span gases, quality control samples, surrogate samples, calibration standards and devices, reagent checks.

12) Performance and System Audits

This section describes the internal and external reviews that are required to monitor the capability and performance of the measurement systems. System audits evaluate all individual components of the measurement systems to review their selection and use. Performance audits determine the accuracy of the total measurement system.

13) Preventive Maintenance

This section includes schedules and procedures of preventive maintenance on designated equipment, and lists critical spare parts to minimize down time.

14) Specific Routine Procedures Used to Assess Data Precision, Accuracy and Completeness

This section includes the routine statistical procedures used to assess the quality of data for each applicable parameter.

15) Corrective Action

This section includes corrective action procedures for the project. Procedures identify data acceptability limits beyond which corrective actions are required, and responsible staff for implementing corrective actions.

16) Quality Assurance Reports to Management

This section identifies the project's periodic reports to management on the performance of measurement systems and data quality.

d. Discuss the Department's responsibilities for the implementation, assessment, and improvement of Quality Assurance Programs

Implementation (DOE Order 5700.6C)
Senior management should:

- establish and cultivate principles and practices that integrate quality requirements into daily work,
- provide individuals performing the work the proper information, tools, support, and encouragement to properly perform their assigned work,
- define requirements, properly train, motivate and empower personnel, provide appropriate resources and assess performance,
- demonstrate commitment and leadership to achieve quality through active involvement in the implementation of an effective quality assurance program.

The individual's role is to meet the quality requirements while recommending improvements in item and process quality.

In structuring the organization and assigning responsibilities, quality assurance should be recognized as an interdisciplinary function involving many organizational components and should not be regarded as the sole domain of any single quality assurance group. Achieving quality is the responsibility of people throughout the organization, from the top executives to workers, including designers, scientists, engineers, welders, inspectors, researchers, operators, craftsmen and auditors.

Assessment (DOE Order 5700.6C)
Senior management should:

- plan and implement self assessments of their quality assurance program to evaluate effectiveness and identify management problems that impair the organization from achieving objectives,
- retain overall responsibility for management assessments,
- directly participate in management assessments,
- involve all other levels of management as appropriate,
- once assessment results and recommendations are documented, make and document decisions and take prompt action,
- evaluate the effectiveness of these actions.

The Department should establish a group to perform independent assessments of quality assurance programs. This group should plan and implement assessments to suggest or promote improvements in the quality of processes and products.

Improvement (DOE Order 5700.6C)
Management at all levels should:

- be involved in the quality improvement process to ensure that proper focus is given, adequate resources are allocated and difficult issues are resolved,
- establish and implement a process for resolving professional differences of views and opinions,
- foster a no-fault attitude to encourage the identification of nonconforming items and processes, and to suggest improvements,
- grant staff the freedom and authority to stop work until effective corrective actions are taken,
- promote continuous improvement, which may include improving expected performance standards and measures.

e. Describe the purpose, origination process, review process, and approval process for Quality Assurance procedures.

The purpose of quality assurance procedures is to ensure work is done right the first time. Excerpts from various sources regarding the purpose of quality assurance procedures are provided below.

- DOE Order 5700.6C *Quality Assurance*, Criteria 5 Work Processes states; "work should be planned, authorized and accomplished under controlled conditions using technical standards, instructions, procedures, or other

appropriate means of detail commensurate with the complexity and risk of the work."

• NQA-1 *Nuclear Quality Assurance* Basic Requirement 5 Instructions Procedures and Drawings states; "Activities affecting quality shall be prescribed by and performed in accordance with documented instructions, procedures, or drawings of a type appropriate to the circumstances. These documents shall include or reference appropriate quantitative or qualitative acceptance criteria for determining that prescribed activities have been satisfactorily accomplished."

• QC-1 *Quality Criteria* under Section IV *Production Quality Requirements*, Part 2 Instructions and Procedures; "Manufacturing, inspection, and testing activities shall be consistent with design requirements and shall be prescribed by documented work instructions, procedures, drawings, or specifications. These documents shall include or reference appropriate criteria for determining that activities have been accomplished in a satisfactory manner. Work instruction documents shall be available to the operators and shall be followed."

The best guide for specifics on the three procedure process steps (origination, review and approval) for an organization is their document control system. Based on the philosophy that quality assurance is incorporated into all work performed, all working procedures, instructions or guidelines have quality assurance elements and aspects that are best drafted, reviewed and approved by the organization performing the work.

Examples

• Aspects of a document control system are reflected in the attachment to DOE Order 5700.6C *Quality Assurance*, Criteria 4 Documents and Records. This states that a document control system; "should be established and implemented to control preparation, review, approval, issuance, use and revision of documents that establish policies, prescribe work, specify requirements or establish design."

• RFFO's *Quality Assurance Requirements for Rocky Flats Management and Operations*, Chapter 5 Instructions, Procedures and Drawings states; "A documented review of instructions, procedures, and drawings shall be performed by the originating organization to assure technical adequacy and inclusion of quality assurance requirements."

Responsibility and authority in the procedure process for other organizations is summed up in RFI 5700.6 *Quality Assurance* under requirement (b)(2) Acceptance of Implementation Plans and Procedures which states; "Quality assurance program plans and descriptions of proposed programs to be implemented at Rocky Flats are to be submitted to the next higher level in the organizational hierarchy. These plans or descriptions are to be reviewed and accepted for implementation on Rocky Flats work. In the event these plans or descriptions are determined to be inadequate or otherwise unacceptable, appropriate direction is to be provided to the performing organization, with follow-up actions, to resolve the inadequacy."

f. Discuss the purpose, the implementation process, and the reporting process associated with Quality Assurance Audits.

Definition and Purpose
RFFO's Quality Assurance group typically refers to Level 1 Evaluation Activities as "audits."

QADP 5700.6-03 *Level 1 Evaluation Activities* includes the following definitions that outline the purpose of conducting quality assurance audits.

A Level 1 Evaluation is defined as "a planned and documented activity performed to determine by investigation, examination, or evaluation of objective evidence the adequacy of, and compliance with, established requirements and the effectiveness of their implementation." These activities are described as team efforts that may require one to two weeks.

The term "audit" should not be confused with other evaluation activities, such as Level 2 or 3 evaluations, that are performed for the sole purpose of process control or product acceptance.

A Level 2 Evaluation is defined as "a planned and documented activity which, like a Level 1 evaluation, is performed to verify programmatic compliance, but whose scope, resource requirements, and other parameters are less extensive." These activities are described as requiring one or two people and two to five days.

A Level 3 Evaluation is defined as "a review by monitoring or observing ongoing work, examining records, or performing hand-on inspections of material for the primary purpose of production process control or product acceptance." These activities are described as requiring one person and two to eight hours.

Implementation Process

1) Planning and Scheduling

RFFO's quality assurance group produces an annual plan of its evaluation activities. These activities include audits, appraisals, surveillances, reviews and surveys. These activities regard RFFO and contractor programs, activities and operations.

2) Audit Preparation Activities

Examples of applicable preparatory activities include:
- assign staff to the audit team,
- coordinate with other RFFO groups for joint reviews,
- provide an audit notification letter to the organization to be audited,

- identify or collect information to use to plan and conduct the audit (such previous reviews on the subject area, history of nonconformances, subject area procedures or instructions, governing requirements and standards),
- draft the Audit Plan, and
- brief and prepare the audit team.

3) Preparing the Final Audit Plan Package

This package consists of the final audit plan, and the inspection checklists or procedures to follow to perform the audit. The package assigns specific activities to audit team members. If checklists are used, they usually identify items and activities to review, and questions to pursue to determine the true condition of the item or activity under scrutiny.

4) Pre-Audit Conference

The purpose of the pre-audit conference is to
- inform the audited organization of the scope, plan and schedule of the audit,
- introduce the audit team members and establish lines of communication, and
- gain access to information, areas and cooperation of key personnel.

5) Conducting the Audit

The audit is conducted using the Audit Plan Package.
The audit team:
- observes work activities, interviews personnel, examines records and other documentation,
- records observations and findings,
- provides assessments of whether audited processes and procedures are effectively implemented, and are adequate to comply with governing requirements and standards,
- makes recommendations.

The Audit Team Leader compiles and validates observations and findings from all team members as either meritable or deficient.

6) Post-Audit Conference

The purpose of the post-audit conference is to share with the audited organization the observations, issues and deficiencies revealed by the audit. The intent is to ensure that deficiencies are valid and understood, and to direct the audited organization to propose corrective actions.

<u>Reporting Process</u>

7) Post-Audit Activities / Audit Report

The Audit Team Leader prepares the formal audit report with input from audit team members. This report defines all deficiencies in sufficient detail to place each problem in proper perspective and to facilitate response, resolution and follow-up for closure. The auditing group issues the report to the audited organization and requests a formal response to each deficiency.

8) Audit Follow-up and Closure

The Audit Team Leader records audit information in the appropriate tracking databases to prompt for revisiting and eventual closure of findings. These databases may include RFFO's Issues Management System and internal tracking systems used by the auditing group.

The Audit Team Leader evaluates proposed corrective actions for acceptability, verifies and documents their completion when done, and documents the closure of the audit when all findings are addressed.

The Audit Team Leader ensures that the audit working file contains all pertinent documents, such as audit notification, correspondence, checklists, planning and supporting materials, audit report and closure verifications.

9) Records

Upon audit closure, the Audit Team Leader closes out entries in applicable tracking databases, and enters the audit working file into the permanent site records in accordance with QADP 5700.6-06 *Identifying, Classifying and Preparing Documents as Quality Records*.

g. Discuss the relationship between Quality Assurance and Quality Control.

QAMS-004 *Guidelines and Specifications for Preparing Quality Assurance Program Plans* includes the following definitions.

quality assurance—the total integrated program for assuring reliability of monitoring and measurement data

quality control—the routine application of procedures for obtaining prescribed standards of performance in the monitoring and measurement process

In other words, quality assurance regards the whole program, the big picture, the requirements and standards that are goals and that define adequacy. Quality control are the routine checks that take place in the conduct of work to ensure the work is being done right and is in compliance.

For example, a quality assurance review may examine whether or not the guiding standards are set too low or too high or just right for the work process addressed. This type of review may also examine if the correct standards are being used, or interpreted appropriately for the situation at hand.

Meanwhile, a quality control review may look at the details within the work process itself, if defined, to determine the effectiveness of routine checks in the process intent on keeping variation within limits and preventing errors from being overlooked.

h. Referring to DOE Order 5480.26, "Trending and Analysis of Operations Information Using Performance Indicators", discuss the purpose as it relates to Quality Assurance issues.

This order was replaced in DOE's 1995 reorganization with DOE Order O 210.1 *Performance Indicators and Analysis of Operations Information*, dated 9/27/95.

This new 3-page order addresses the need to use performance indicators to evaluate the contractor's work. This is revealed through the objective of using the performance indicators to reveal improving or deteriorating trends. Performance indicators are also to be used as a means to suggest further improvement through the identification of good practices and lessons learned. Work *quality* indicators are not specifically addressed due to the general wording of the order, but are within the scope of intent.

Another quality assurance aspect of the order is the requirement to periodically review the selection of performance indicators to verify that they are accurately measuring performance and can provide information to improve performance.

i. Discuss the purpose and requirements of 10 CFR 830.120.

DOE codified its quality assurance order (5700.6C *Quality Assurance*) as a federal regulation titled 10 CFR 830.120, *Quality Assurance Requirements*. The regulatory language is virtually identical to the order language. There are minor changes in word choice that do not affect the meaning—they just make the document more succinct. 10 CFR 830.120 is a subset of 10 CFR 830 *Nuclear Safety Management*.

The purpose, requirements and criteria of the regulations are the same as the order which is discussed in this study guide under Section 4.1, a. For ease of reference, the ten quality assurance criteria discussed in 10 CFR 830.120 and in DOE order 5700.6C are listed below:

(1) Management
  (i) Program
  (ii) Personnel Training and Qualification
  (iii) Quality Improvement
  (iv) Documents and Records
(2) Performance
  (i) Work Processes
  (ii) Design

(iii) Procurement
(iv) Inspection and Acceptance Testing

(3) Assessment
(i) Management Assessment
(ii) Independent Assessment

SECTION 5: INDUSTRIAL SAFETY

5.1 Personnel shall demonstrate knowledge of the Occupational Safety and Health Act (OSHA) necessary to identify safe/unsafe work practices.

Passed in 1970, the Occupational Safety and Health Act imposes numerous requirements on the Department of Energy. The common element of all the requirements is the stated goal of achieving a safe and healthful workplace for all employees - contractor employed or federally employed. The requirements are initiated by OSHA, codified through the 29 CFR 1900s, reiterated in DOE Orders, and finally implemented at Rocky Flats through the Health and Safety Practices Manual.

a. Describe DOE's responsibilities with respect to OSHA including the following:

Hazard recognition and evaluation. - In addition to the Operational Safety Analysis (OSA) and Job Safety Analysis (JSA) discussed below, Rocky Flats attempts to meet its obligations for hazard recognition and evaluation through a Hazard Assessment Inventory process. The process is controlled by Health & Safety Practices (HSP) procedure 1-15310-HSP-9.13, Hazard Assessment Inventory. The process is designed to ensure that Industrial Hygiene/Occupational Safety hazards within a general area or associated with a specific process are identified and compiled in a database.

The Hazard Assessment Inventory has many uses. For example, it could be used to:

(1) inform employees about hazards that exist within their workplace.

(2) assist in planning work safely.

(3) establish surveillance strategy for the building's health and safety inspection program.

Accident investigation - OSHA requires that accidents involving a fatality or the hospitalization of five or more employees be investigated to determine the causal factors involved.

Typical accident investigation reports include the time, date, and location of the accident, along with a description of the operations at the workplace, a description of the accident itself, photographs, interview results, and additional information determined relevant by the investigator. Any information discovered during an accident investigation which would be of use in developing a new OSHA standard or modifying/revoking an existing standard is transmitted to the Secretary of Labor.

Hazard reduction/elimination - Hazard reduction/elimination or abatement/control programs include:

- Developing procedures to control the access to hazardous chemicals, materials, and activities by utilizing engineering controls, work practices and administrative controls that limit worker exposures.
- Implementing interim protective measures when required based upon risk assessments which indicate a danger to worker. In all cases the workers must be protected immediately from imminent danger conditions until final abatement of the hazard.
- Ensuring potential hazards are addressed when selecting or purchasing equipment, products, and services to minimize the introduction of any new hazards and/or to prevent an increase in any existing hazardous condition.
- Tracking of the hazards to final abatement or disposition.

HSP procedure 1-E35-HSP-1.06 describes the process for the identifying and reporting hazards, determining Risk Assessment Codes, mitigating and abating the hazard, tracking the hazard and corrective actions and verifying the corrective actions have been completed satisfactorily. This process is to ensure that all applicable hazards are identified.

Job Safety Analysis - Per HSP 2.11, “Job Safety Analysis (JSA)” is defined as “breaking down into its component parts any work method, process system, or work activity in order to determine the hazards therein and the requirements or qualifications for those who are to perform work; identifying hazards associated with each step or task and implementing adequate solutions to eliminate, nullify, or reduce to a minimum the consequences of such hazards. The job supervisor is responsible for preparing a JSA. A JSA is similar to a Operational Safety Analysis (OSA), except that a JSA is used for non-routine operations such as testing operations.

The development of a JSA is in five steps:

(1) Sequencing of Project Activities. The work activities are listed in the sequence of performance with a description of what each activity accomplishes.

(2) Identification of Hold Points. Hold points are the points in a work activity which, for safety precaution reasons, require an inspection, certification, or verification prior to continuing work. Examples would be a supervisor verifying appropriate electrical safety precautions have been met prior to working on energized gear or industrial hygiene inspecting for asbestos.

(3) Determining Work Activity Hazards. Specific hazards are identified by considering things like whether a worker could slip or fall, be caught between objects, be exposed to a hazardous environment, etc.

(4) Determining Human Error Hazards. Specific hazards are identified by considering things like whether the work is repetitive in nature, whether the equipment is particularly difficult to operate, whether the procedures are too complicated, etc.

(5) Applying Safety Measures. Safety measures which eliminate or control the identified hazards are specified.

The specifics on OSAs are contained in HSP 2.03. OSAs are required to be reviewed annually.

Accident/injury/illness prevention - Accident/Injury/Illness Prevention requires a proactive program to ensure that accidents, injuries, and illnesses do not occur or have an opportunity to occur. This includes:
- Safety meetings and Inspections.
- A Lockout/Tagout system.
- Operational Safety Analysis.
- Job Safety Analysis.
- Protective equipment.
- Hazard communication.
- Occupational safety.
- Industrial hygiene.
- Electrical safety.
- Radiation safety.
- Explosives safety.
- Environmental safety.
- Construction safety.
- Motor vehicle and pedestrian safety.
- Fire prevention.

Blood-Borne Pathogens - Universal Precautions are to be implemented to prevent contact with blood or other bodily fluids. This concept involves an approach to infection control in occupational settings to treat all human blood and certain bodily fluids as if they are known to be infectious for Human Immunodeficiency Virus (HIV), Hepatitis B Virus (HBV), Hepatitis C Virus (HCV), and other blood-borne pathogens. HSP 1-H28-HSP-4.17 provides guidance on meeting the concept above with respect to 29 CFR 1910.1030. This procedure covers:
- Engineering and work practice controls.
- Contaminated equipment.
- Personal Protective Equipment.
- Hepatitis B vaccination or exposure incident.
- Housekeeping, cleaning, and decontamination.

b. Using references, discuss the purpose of 29 CFR 1910, Occupational Safety and Health Standards.

29 CFR 1910 satisfies the requirement of Section 6(a) of the Occupational Safety and Health Act. Section 6(a) requires that the Secretary of Labor "...by rule promulgate as an occupational safety or health standard any national consensus standard, and any established Federal Standard, unless he determines that the promulgation of such a standard would not result in improved safety or health..." 29 CFR 1910, therefore, is basically a voluminous

list of industry standards, usually with a summary and occasionally additional requirements, for topics ranging all the way from electrical safety to commercial diving operations.

c. Using references, discuss the purpose of 29 CFR 1960, Basic Program Elements for Federal Employee Occupational Safety and Health Programs and Related Matters.

29 CFR 1960 ties together requirements found in Section 19 of the Occupational Safety and Health Act and Executive Order 12196, Occupational Safety and Health Programs for Federal Employees. Section 19 of the OS&H Act contains requirements to provide safe and healthful working conditions for federal employees. It also assigns the responsibility for the establishment and maintenance of a comprehensive and effective occupational safety and health program, consistent with the standards established in Section 6 of the OS&H Act, to the head of each federal agency.

Executive Order 12196 contains additional requirements. Specifically, the Secretary of Labor is required to issue program elements which the heads of agencies are required to incorporate into their safety and health programs.

29 CFR 1960 contains 11 subparts which are listed below:

Subpart A - General
Subpart B - Administration
Subpart C - Standards
Subpart D - Inspection and Abatement
Subpart E - General Services Administration and other Federal Agencies
Subpart F - Occupational Safety and Health Committees
Subpart G - Allegations of Reprisal
Subpart H - Training
Subpart I - Recordkeeping and Reporting Requirements
Subpart J - Evaluation of Federal Occupational Safety and Health Programs
Subpart K - Field Federal Safety and Health Councils

Subpart D - Inspection and Abatement, is one of the most useful and important portions of the rule therefore it is discussed in more detail below. Subpart D includes sections discussing:

(1) the requirements for the qualifications of safety and health inspectors.

(2) the conduct of inspections.

(3) the role of representatives of management and employees during an inspection.

(4) the protocol for submittal and processing of employee reports of unsafe or unhealthful working conditions.

(5) the requirement to conduct accident investigations.

(6) the requirement to promptly address and abate unsafe or unhealthful working conditions.

(7) the authority for OSHA to conduct their own, independent workplace inspections, if they deem it necessary.

d. Discuss the regulatory interfaces between OSHA and other regulatory agencies.

As discussed above, OSHA standards are required to be incorporated into all federal agency health and safety programs. In addition to OSHA requirements, an agency may be required to comply with additional standards outside the OSHA realm.

Although it is not anticipated that agency standards will conflict with OSHA standards, the Secretary of Labor must be notified when a conflict exists. Until the conflict is resolved, the affected agency is expected to comply with the most conservative of the standards.

e. Discuss the conduct of occupational safety & health inspections.

As always, inspections can be broken down into three distinct phases: preparation, performance, and reporting. The basic process is the same whether you're an OSHA employed inspector, a member of a facility's health and safety committee performing a monthly surveillance, or an oversight person walking through a production area.

All inspections begin with preparation. For a formal inspection, all information which pertains to the safety and health of the workplace should be obtained before arriving for the inspection. Appropriate information would include: a hazard assessment inventory report, injury and illness records, previous inspection reports, and any reports of unsafe or unhealthful working conditions. Based on the information received, the inspector should determine the actual work procedures or conditions to be observed.

After preparation comes performance. The CFRs are clear about access for formal health and safety inspections. Specifically:

- Inspectors shall be able to enter without delay, and at reasonable times, any building, installation, facility, construction site, workplace, or environment where work is performed by employees.

- Inspectors shall be able to inspect and investigate any place of employment and all pertinent conditions, structures, machines, apparatus, devices, equipment, and materials within the workplace.

- Inspectors shall be able to question privately any employee or supervisor.

Whenever the inspector determines that a danger which could reasonably be expected to cause death or serious physical harm exists, the inspector shall inform employees and management of the condition. Management shall take immediate abatement action and evacuate unnecessary personnel. At the conclusion of the inspection, the inspector shall out brief management on the results of the inspection. The above should apply, less some formality, to DOE oversight personnel also.

The inspection report completes the process. For a formal inspection:

- The inspector must describe, in writing, the actual conduct of the inspection and any findings identified. Any safety violation notices must be issued within 15 days, while health violation notices must be issued within 30 days. Facilities must post any notice received in the workplace.

- Any notice issued must describe the nature and degree of seriousness of the violation along with reference to the standard or requirement being violated.

f. Discuss the major components of the OSHA Hazard Communication Protocol.

Major components of hazard communication include:

- Identifying and evaluating a hazardous chemical.
- Maintaining an inventory or list of hazardous chemicals and locations.
- Labeling of containers of chemicals with the following minimal information:
  - Identity of the hazardous chemical.
  - Appropriate hazard warnings.
  - Name and address of the chemical manufacturer, importer, or other responsible party.
- Preparation and distribution of material safety data sheets (MSDS) to employees and downstream employers. (The information found on an MSDS is discussed below in section 5.5, b.)
- Development and implementation of employee training programs regarding hazards of chemicals and protective measures.
- Guidance on acquisition of hazardous chemicals.
- Guidance on transportation of hazardous materials.
- Guidance on handling, use, and storage of hazardous chemicals.
- Surveillances.

HSP 1-15310-HSP-9.07 describes the Hazard Communication program at Rocky Flats.

g. Using references, discuss the purpose of the following DOE orders:

3790.1B Federal Employee Occupational Safety and Health Program - This Order was replaced by DOE Order 440.1 with the exception of Chapter VIII of DOE Order 3790.1B, "Federal Employee Occupational Medical Program." The purpose of the order is still the same which is to establish a framework for an effective worker protection program that will reduce or prevent accidental losses injuries, and illnesses by providing DOE Federal and contractor workers with a safe and healthful workplace.

5480.1B Environmental, Safety, and Health Programs for DOE Operations - This Order was replaced by DOE Order 440.1 with the exception of Chapter VIII of DOE Order 3790.1B, "Federal Employee Occupational Medical Program." The purpose of the order is still the same which is to establish a framework for an effective worker protection program that will reduce or prevent accidental losses injuries, and illnesses by providing DOE Federal and contractor workers with a safe and healthful workplace.

5483.1A Occupational Safety and Health Program for DOE Contractor Employees at Government-Owned-Contractor-Operated (GOCO) Facilities - This Order was replaced by DOE Order 231.1, Environment, Safety and Health Reporting and DOE Order 440.1, Worker Protection Management for DOE Federal and Contractor Employees. The purpose of DOE Order 440.1, which is the main document covering the topics in DOE Order 5483.1A is defined above. The purpose of DOE Order 231.1 is "to ensure collection and reporting of information on environmental, safety and health that is required by law or regulation to be collected, or that is essential for evaluating DOE operations and identifying opportunities for improvement needed for planning purposes within the DOE."

5.2 Personnel shall demonstrate knowledge of Fire Safety for Department facilities necessary to identify safe/unsafe work practices.

a. Discuss the critical aspects of fire protection, emergency planning and control of fires.

Fire protection is a broad term which encompasses all aspects of fire safety, including: building construction and fixed building fire features, fire suppression and detection systems, fire water systems, emergency process safety control systems, emergency fire fighting organizations (fire departments, fire brigades, etc.), fire protection engineering, and fire prevention. Fire protection is concerned with preventing or minimizing the direct and indirect consequences of fire. It also includes aspects of the following perils as they relate to fire protection: explosion, natural phenomenon, smoke and water damage from fire. Information from the fire protection program shall be incorporated in the Emergency Plan. The facility fire protection organization shall be involved in the development of the Emergency Plan and in all related training and drills.

b. Describe fire hazards that could affect the safety of facility personnel.

A fire hazard exists any time you have the combination of a heat energy source, combustible material (fuel), and available oxygen (air). Plutonium is a material that is its own heat source and can be pyrophoric under certain conditions and forms (metal fines, metal shavings, oxide that has not yet been stabilized, hydride, minimal oxygen environment). Other combustible materials (wood staging platforms, flammable liquids, paper absorbents, etc.) can be fire hazards in a facility and thus require controls such as maximum allowed quantities (combustible loading) and proper storage locations. Electrical fires can occur due to excessive loading of circuits and poorly maintained electrical/electronic equipment.

c. Discuss the key elements of the National Fire Protection Association (NFPA) Life Safety Code.

The scope of the NFPA Life Safety Code (NFPA 101) is as follows:

> "1-3.1 This Code addresses life safety from fire and similar emergencies.
>
> 1-3.2 The Code addresses those construction, protection, and occupancy features necessary to minimize danger to life from fire, smoke, fumes, or panic.
>
> 1-3.3 The Code identifies the minimum criteria for the design of egress facilities so as to permit prompt escape of occupants from buildings or, where desirable, into safe areas within the building.
>
> 1-3.4 The Code recognizes that life safety is more than a matter of egress and, accordingly, deals with other considerations that are essential to life safety.
>
> 1-3.5 When in fixed locations and occupied as buildings: vehicles, vessels, or other mobile structures shall be treated as buildings.
>
> 1-3.6 The Code does not attempt to address those general fire prevention or building construction features that are normally a function of fire prevention and building codes.
>
> 1-3.7 The prevention of accidental personal injuries during the course of normal occupancy of buildings, personal injuries incurred by an individual's own negligence, and the preservation of property from loss by fire have not been considered as the basis for any of the provisions of this Code."

The *Fundamental Requirements*, quoted below, are the key elements that are further elaborated upon for specific building occupancy types later in the Code:

> "2-1 Every building or structure, new or old, designed for human occupancy shall be provided with exits and other safeguards sufficient to permit the prompt escape of occupants or furnish other means to provide

a reasonable degree of safety for occupants in case of fire or other emergency. The design of exits and other safeguards shall be such that reliance for safety to life in case of fire or other emergency will not depend solely on any single safeguard; additional safeguards shall be provided for life safety in case any single safeguard is ineffective due to some human or mechanical failure.

2-2 Every building or structure shall be so constructed, arranged, equipped, maintained, and operated as to avoid undue danger to the lives and safety of its occupants from fire, smoke, fumes, or resulting panic during the period of time reasonably necessary for escape from the building or structure or for that period of time needed to defend in place in case of fire or other emergency.

2-3 Every building or structure shall be provided with exits and other safeguards of kinds, numbers, locations, and capacities appropriate to the individual building or structure, with due regard to the character of the occupancy, the capabilities of the occupants, the number of persons exposed, the fire protection available, the height and type of construction of the building or structure, and other factors necessary to provide all occupants with a reasonable degree of safety.

2-4 In every building or structure, exits shall be so arranged and maintained as to provide free and unobstructed egress from all parts of the building or structure at all times when it is occupied. No lock or fastening shall be installed to prevent free escape from the inside of any building. Exits shall be accessible to the extent necessary to assure reasonable safety for occupants having impaired mobility.

2-5 Every exit shall be clearly visible, or the route to reach every exit shall be conspicuously indicated in such a manner that every occupant of every building or structure who is physically and mentally capable will readily know the direction of escape from any point. Each means of egress, in its entirety, shall be so arranged or marked that the way to a place of safety is indicated in a clear manner. Any doorway or passageway that is not an exit or a way to reach an exit, but is capable of being confused with an exit shall be so arranged or marked to prevent occupant confusion with acceptable exits. Every effort shall be taken to avoid occupants mistakenly traveling into dead-end spaces in a fire emergency.

2-6 Where artificial illumination is required in a building or structure, exit facilities shall be included in the lighting design in an adequate and reliable manner.

2-7 In every building or structure of such size, arrangement, or occupancy that a fire itself may not provide adequate occupant warning, fire alarm facilities shall be provided where necessary to warn occupants of the existence of fire. Fire alarms will alert occupants to initiate

emergency procedures. Fire alarms facilitate the orderly conduct of fire exit drills.

2-8 Two means of egress, as a minimum, shall be provided in every building or structure, section, and area where their size, occupancy, and arrangement endanger occupants attempting to use a single means of egress that is blocked by fire or smoke. The two means of egress shall be arranged to minimize the possibility that both may be rendered impassable by the same fire or emergency condition.

2-9 Every vertical way of exit and other vertical opening between floors of a building shall be suitably enclosed or protected, as necessary, to afford reasonable safety to occupants while using exits and to prevent spread of fire, smoke, or fumes through vertical openings from floor to floor before occupants have entered exits.

2-10 Compliance with the Code shall not be construed as eliminating or reducing the necessity for other provisions for safety of persons using a structure under normal occupancy conditions. Also, no provision of the Code shall be construed as requiring or permitting any condition that may be hazardous under normal occupancy conditions."

d. Discuss the purpose of Fire Hazard Analysis.

The purpose of a fire hazards analysis (FHA) is to comprehensively assess the risk from fire within individual fire areas in a DOE facility in relation to existing or proposed fire protection so as to ascertain whether the objectives of DOE Order 5480.7A (now found in 420.1 and 440.1) are met. The FHA is developed using a graded approach, is ultimately incorporated into the facility's Safety Analysis Report, and is integrated into design basis and beyond design basis accident conditions. A graded FHA shall contain, but not be limited to, the following elements: (a) Description of construction, (b) Protection of essential safety class equipment, (c) Fire protection features, (d) Description of fire hazards, (e) Life safety considerations, (f) Critical process equipment, (g) High value property, (h) Damage potential [Maximum Credible Fire Loss (MCFL) and Maximum Possible Fire Loss (MPFL)], (I) Fire Department/Brigade response, (j) Recovery potential, (l) Potential for a toxic, biological and/or radiation incident due to a fire, (m) Emergency planning, (n) Security considerations related to fire protection, (o) Natural Hazards (earthquake, flood, wind) impact on fire safety, and (p) Exposure fire potential, including the potential for fire spread between fire areas.

e. Describe the characteristics and methods/agents used to extinguish the following classes of fires:

Class A - These are fires involving combustibles such as wood, paper, cloth, etc. These fires are typically extinguished with water or a dry chemical fire extinguisher. Halon is also effective. Carbon dioxide may also be used but is only effective for small fires.

Class B - These are fires involving liquids (lubricating oil, fuel oil, diesel fuel, gasoline, kerosene, etc.). These fires are extinguished with a foaming agent, a chemical agent such as pkp or a dry chemical fire extinguisher. A water fog is marginally effective if applied properly. Halon can be effective also.

Class C - These are fires involving electrical circuits. The circuit must be de-energized in order to remove the heat source. Carbon dioxide and halon are the principle extinguishing agents. Water is not used due to the associated shock hazard if the circuits are energized. Chemical agents are also not recommended due to their corrosive nature although a dry chemical fire extinguisher would be effective against a class C fire.

Class D - These are fires involving burning metal (e.g., plutonium, magnesium, sodium, lithium, etc.). These fires are typically extinguished using an inert smothering agent such as magnesium oxide, sand, or a dry powder fire extinguisher. Metal fires are extremely hard to put out because of the extreme heats that are produced. Plutonium will continue "burning" in relatively low oxygen concentration environments once the process gets started.

f. Discuss the key components and use of building fire protection equipment including:

Detection, alarm, and communication systems
Extinguishing systems (automatic and manual)

Fire protection is comprised of a comprehensive system of defense against the fire hazard for the benefit of both personnel and the facility itself. It starts with good fire prevention practices (good housekeeping, proper storage of flammable materials, minimizing combustible loading, etc.) and facility design (use of fire walls, fire doors in glovebox lines, sprinkler and other suppression systems, avoidance of layouts that promote updrafts, etc.). Next comes the use of **fire detection systems** as close to the potential sources as possible (e.g., storage trays equipped with heat detection in the gloveboxes, temperature probes in the ventilation ducting before reaching the plenums, trained operators, etc.). Detection systems are used to drive both **alarms** to warn personnel and alert fire department personnel, and to activate automatic fire suppression systems. **Communication systems** enable operating personnel to quickly notify the fire department as well as other facility personnel of a fire condition through the use of pull-stations and/or sound-powered phones, with direct lines to the fire department, at or close to operating stations. **Fire suppression (extinguishing) systems** include sprinkler systems, plenum deluge systems, halon discharge systems and carbon dioxide discharge systems that activate either automatically or manually. **Portable extinguishers** are installed throughout the facility to enable trained, personnel to take immediate action to control a small fire before it spreads into a larger one until the fire department can arrive. A **supervisory alarm system** is also used to detect faults in the system**.** Periodic surveillance testing ensures that fire panels and detectors are continuously operable.

g. Using references, discuss the purpose of DOE Order 5480.7A, Fire Protection.

DOE Order 5480.7A was superseded by DOE Order 420.1, Facility Safety, and DOE Order 440.1, Worker Protection Management for DOE Federal and Contractor Employees. The purpose of the 420.1 order is "to establish facility safety requirements related to" fire safety, among other things (see para. 4.2). The purpose of the 440.1 order is "to establish the framework for an effective worker protection program that will reduce or prevent accidental losses, injuries, and illnesses by providing DOE Federal and contractor workers with a safe and healthful workplace," which includes implementation of a "comprehensive fire protection program" (see Attachment 1, para. 2). Para. 4.2.1 of Order 420.1 defines a "comprehensive fire and related hazards protection program for facilities" to be one that is "sufficient to minimize the potential for:

(1) the occurrence of a fire or related event;

(2) a fire that causes an unacceptable on-site or off-site release of hazardous or radiological material that will threaten the health and safety of employees, the public or the environment;

(3) vital DOE programs suffering unacceptable interruptions as a result of fire and related hazards;

(4) property losses from a fire and related events exceeding defined limits established by DOE; and

(5) critical process controls and safety class systems being damaged as a result of a fire and related events."

5.3 Personnel shall demonstrate knowledge of the principles of electrical safety, referring to OSHA standards and the National Electrical Code, necessary to identify safe/unsafe work practices.

a. Discuss the types of protection afforded by the following:

Fuses - A fuse is a device that protects equipment from an overcurrent condition that would otherwise damage the equipment. When its rated current is reached the fuse will melt and thereby open the circuit. It is good for only one application of over-current because it is destroyed in the process.

Grounding devices - Grounding devices protect personnel from electric shock, usually in the case of an equipment fault involving a short to the case. Machinery is often grounded by attaching a metal braided strap at one end to the casing and at the other end to building steel, a water pipe that is in contact with the ground, or a stake that is imbedded into the ground (earth). Portable equipment utilize a grounded power plug with the ground wire of the power cord attached to the case. Another type of grounding device is called a ground fault interrupter (GFI) which is normally built into a power receptacle. This device is a

very sensitive type of circuit breaker. It will detect if current is flowing through the ground portion of the circuit (a fault condition) and open the power circuit.

Circuit breakers - Circuit breakers have the same protective function as fuses in that they protect equipment from an overcurrent condition. They will "trip" to open the circuit when the set current is exceeded for a specific duration of time. The trip current set point and time duration specifications are determined by the circuit designer based on the needs of the system. A circuit breaker, unlike a fuse, can be reset and used again. Circuit breakers can also be manually tripped so as to function like a switch for removing the power source from a piece of equipment or an entire system. They are usually equipped with a means of locking the operating lever to prevent closure during maintenance.

b. Discuss conditions which may result in electrical shock.

An electrical shock can occur whenever a person makes contact with an electrical circuit in such a way as to provide a better path (through the body) to ground (less resistance) that would exist otherwise. Electricity flows fairly well through water and the human body is made up of mostly water. The skin offers some resistance to current flow if it is dry but is compromised by even a little perspiration. Therefore any wet or moist environment can increase the likelihood of electrical shock.

Electrical equipment without the proper lighting and clearances in front and to each side of the equipment can subject electricians and maintenance workers to electrical shocks. Someone working in a cramped or poorly lit space is more likely to accidentally touch an energized circuit. There are two main clearances required for electrical equipment to ensure protection for personnel from electrical shocks and burns. The first clearance is to maintain a measurement of 30 inches wide in front of the equipment and secondly a clearance of at least 3 ft. is required outwardly in front of all electrical equipment (2' 6" for equipment installed before April 16, 1981). Lighting fixtures must have a head room clearance of at least 6 1/2 ft. to give personnel sufficient room to stand in front of electrical equipment without a threat of their head or head gear contacting metal.

Proper grounding is essential to protect electrical systems from dangerous over voltages, ensure the tripping of the overcurrent protection devices, and protect personnel from electrical shock.

Exposed conductors create a potential for shock. Wiring insulation that is in poor condition (cracked, brittle, frayed, etc.) can provide a false sense of safety and is probably the most common shock hazard.

The wearing of jewelry and other conductive objects (e.g., watch bands, bracelets, rings, key chains, necklaces, metalized aprons, cloth with conductive thread, and metal headgear) by employees working on electrical equipment is very dangerous. Handling of conductive materials and equipment (e.g., long objects, ducts, pipes and tubes, hose and rope, metal-lined rules and scales, steel tapes, chains, etc.) near exposed live electrical components is a shock

hazard and requires that care be taken to prevent their contacting the energized parts.

Failure to use electrical protective equipment that is in a safe reliable condition or follow safe working practices while working on or near energized equipment can result in electrical shock.

Failure to properly lockout and tagout electrical equipment before doing maintenance can result in shock to the person doing the work due to inadvertent operation by an operator.

Several of the above examples of conditions which could result in an electrical shock can be generalized as a failure to follow procedure. Compliance to properly written procedures is essential for all personnel and it plays a very important role in avoiding conditions which could result in an electrical shock.

c. Given a workplace situation involving the use of electrical equipment, identify applicable standards using 29 CFR 1910 Subpart S to determine if the situation is in compliance and discuss the appropriate corrective measures.

Rather than provide an example of a situation and identify only a few deficiencies, the more common errors and corrective actions will be identified. Section 15 of the Health and Safety Practices (HSP) manual provides general guidance on Electrical Safety that covers most of the requirements of 29 CFR 1910 Subpart S.

- When utilizing portable electrical equipment, it should be provided with an equipment grounding conductor which runs with the power conductors in the power cord. It is not allowed to be outside the cord. Underwriters' Laboratories, Inc. (UL) or approved double-insulated portable equipment and hand tools are exempt from the above requirement.
- Flexible electric cords may not be used for raising or lowering equipment. The cords may not be fastened with staples or otherwise hung such that damage to the outer jacket or insulation may occur.
- A visual inspection of the cord and equipment shall be performed before use on any shift for external (loose parts, deformed and missing pins, or damaged to outer jacket or insulation) or internal (pinched or crushed conductors) defects. Equipment that remain connected and are not exposed to damage need not be examined.
- Load rated switches, circuit breakers or other devices specifically designed to be opened and closed under load can be used to break or close a circuit. Components that are not designed for this purpose may only be opened in an emergency.
- After a circuit is de-energized by a circuit protective device, the circuit may not be manually re-energized until the cause of the protective action has been determined and that the equipment and circuit can be safely energized. (Exception: If the cause of the protective action can not be identified, then the circuit protective device may be reset once.)

- At Rocky Flats a Two-Person rule requires the presence of two trained and qualified electrical workers when working on or in close proximity to exposed energized electrical circuits/equipment at or above 480V. The first person performs the work while the second person stands by to render assistance to the first person in the event he/she is inadvertently shocked while performing the work. The second person shall be qualified in CPR and know the location of the isolation device(s) for the equipment being worked on.

If any portable electrical equipment is found not meeting the above requirements, positive control of the equipment should be exercised to ensure the equipment is not used prior to correcting the discrepancy.

d. Discuss the proper method for removing a victim from an energized circuit.

Do not touch the person directly - you will just become part of the circuit and have a shocking experience. The safest way to remove a person from an energized circuit is to de-energize the circuit (if possible) then, as a precaution, use something non-conducting, such as a piece of wood, (e.g., wooden broom handle), rubber, rope, clothing, etc., to pry the person loose. The precaution should be followed because of the possibility of there being multiple sources of power creating some uncertainty that the right circuit is de-energized. The victim's grip may not relax upon the removal of the power source resulting in the need to pry him/her loose. If good practices are being followed to perform electrical work, the person should have a rope tied around his/her waist for the express purpose of pulling them off an energized circuit should it become necessary and be working with a second person who is there for that purpose.

e. Discuss the general guidelines in the DOE Electrical Safety Guidelines, DOE/ID-10600

A copy of this document could not be located at the Rocky Flats Environmental Technology Site. Attempts to obtain the document from the DOE office in Idaho were unsuccessful.

5.4 Personnel shall demonstrate knowledge of hazardous chemicals and hazardous waste operations, treatment, storage, and disposal necessary to identify safe/unsafe practices.

a. Discuss the purpose of the following Departmental Orders:

5480.3 Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances and Hazardous Wastes - This order has been superseded (except para. 9e) by DOE Order 460.1, Packaging and Transportation Safety.

The purpose of 460.1 is to establish the safety requirements for the proper packaging and transportation of DOE offsite shipments and onsite transfers of hazardous materials. Onsite is defined to be any areas within the boundaries of

a DOE site to which public access is controlled. Offsite, therefore, is any area within or outside the boundaries to which the public has uncontrolled access.

5480.4 Environmental Protection, Safety, and Health Protection Standards 5480.4 provides requirements for the application of mandatory environmental protection, safety, and health (ES&H) standards for all DOE and DOE contractor operation. The Order is primarily composed of four attachments:

(1) Attachment 1, Mandatory ES&H Standards (Statutory Requirements). This attachment contains standards that are mandatory due to non-DOE Federal or State ES&H statutes or requirements. Examples include RCRA and CERCLA.

(2) Attachment 2, Mandatory ES&H Standards (Policy Requirements). In addition to standards required by other agencies, DOE has added mandatory standards. Examples include National Fire Codes, OSHA, and National Electrical Codes.

(3) Attachment 3, Reference ES&H Standards. Standards and guidelines specified in this attachment are not mandatory, but are provided as references on good practices and for general informational value.

(4) Attachment 4, Sources of ES&H Standards. The Order felt compelled to provide a mailing list for the organizations from which standards were obtained.

5.5 Personnel shall demonstrate knowledge of industrial hygiene principles.

a. Using references, discuss the purpose of the following DOE Orders:

5480.1 Environmental, Safety, and Health Programs - 5480.1 establishes the Environment, Safety, and Health (ES&H) Program for DOE operations. The Order reiterates the DOE's ES&H policy to: assure the protection of the environment and the health and safety of the public; to assure a safe and healthful workplace; and protect government property against accidental loss and damage. As with all Orders, 5480.1 then goes on to assignment of responsibilities - most of which are delegable - all designed to require a competent, funded ES&H Program at all DOE facilities.

5480.11 Radiation Protection for Occupational Workers - This order was canceled by DOE Notice 441.1. DOE Notice 441.1, when combined with 10 CFR 835 and its associated implementation guidance, form the basis for a comprehensive radiological protection program. Notice 441.1 contains 16 top-level, performance-based requirements to provide critical direction in the areas of administrative controls, radiation safety training, work authorizations, postings, exposure of minors and sealed radioactive source accountability.

5480.9 Construction Safety and Health Program, ***5480.10 Contractor Industrial Hygiene Program, 5483.1 Occupational Safety and Health Program for DOE Contractor Employees at Government-Owned-Contractor-Operated (GOCO) Facilities, and 3790.1 Federal Employee Occupational Safety and Health Program*** have been superseded by DOE Order 440.1 Worker Protection Management for DOE Federal and Contractor Employees.

The purpose of 440.1 is to establish the framework for an effective worker protection program that will reduce or prevent accidental losses, injuries, and illnesses by providing DOE federal and contract workers with a safe and healthful workplace. The Order specifies general requirements for all areas of the program and specific functional area requirements.

The attributes which should be common to all program areas include:

(1) providing workers the right to accompany worker protection personnel during workplace inspections and to express concerns related to worker protection.

(2) implementing procedures to allow workers to stop work when they discover employee exposure to imminent danger.

(3) informing workers of their rights and responsibilities - typically through some type of accessible posting area.

(4) identifying existing and potential workplace hazards and evaluating the risk of associated worker injury or illness.

(5) implementing a hazard prevention/abatement process to ensure all identified hazards are managed through final abatement.

(6) providing workers, supervisors, managers, visitor, and worker protection professionals with appropriate worker protection training.

The functional areas and their requirements are called out in Attachment 1 of the Order. The attachment discusses:

(1) Construction Safety. Requirements are defined for all construction projects which exceed the monetary threshold established by the Davis-Bacon Act. The construction contractor must prepare a hazard analysis, and have it formally approved, prior to the commencement of work for all construction operations. Additionally, workers must be informed of foreseeable hazards and the required protective measures identified in the hazard analysis prior to commencing work. During periods of active construction, the construction contractor must have a designated representative on site. The individual must conduct and document daily workplace inspections.

(2) Fire Protection. A fire protection program with the objective of providing an acceptable level of safety from fire and related hazards must be

implemented. The attachment references DOE Order 420.1, Facility Safety, for more detailed fire protection program requirements.

(3) Firearms Safety. Requirements include:

- having a DOE approved safety analysis for the facility and the operation of each live firing range.

- having trained and qualified personnel.

- developing and using procedures for the storage, handling, cleaning, and maintenance of firearms and ammunition; activities such as loading, unloading, and exchanging firearms; the use of pyrotechnics and/or explosive projectiles; handling misfires and duds; live fire operations; and training and exercises.

- conducting formal assessments of procedure implementation.

(4) Explosives Safety. The attachment references DOE Manual 440.1-1, DOE Explosives Safety Manual, for more detailed fire protection program requirements.

(5) Industrial Hygiene. The basic elements of an industrial hygiene program are spelled out:

- Baseline surveys of all work areas or operations to identify and evaluate potential worker health risks.

- Periodic resurveys and/or exposure monitoring.

- Documented exposure assessment for chemical, physical, and biological agents and ergonomic stressors using recognized exposure assessment methodologies.

- Specification of appropriate engineering, administrative, and personnel protective control methods to limit hazardous exposures to acceptable levels.

- Worker education, training, and involvement.

- Use of DOE accepted respiratory protection.

- Policy and procedures to mitigate the risk from identified and potential occupational carcinogens.

- Use of appropriate industrial hygiene standards.

(6) Occupational Medicine. Program requirements for employee health examinations and medical records are discussed.

(7) Pressure Safety. The requirement for all pressure vessels, boilers, air receivers, and supporting piping systems to conform to the appropriate American Society of Mechanical Engineers (ASME) codes is presented.

(8) Motor Vehicle Safety. Requirements for the safety and health of drivers and passengers in government-owned or -leased motor vehicles and powered industrial equipment is discussed.

b. Discuss the key elements of a Hazards Communication Program and the use of Material Safety Data Sheets (MSDS).

The purpose of the Rocky Flat's Hazards Communication Program is to ensure that employees are properly informed about chemical hazards in the workplace. This is accomplished by maintaining lists of hazardous chemicals site-wide, by using MSDSs in the workplace, by properly labeling chemical containers, and by training.

MSDSs are required by OSHA's Hazards Communication Standard. They provide information concerning chemical hazards and control measures necessary to ensure a safe work environment when working with specific materials. Copies of MSDSs are maintained in binders in each workplace. A master file of all MSDSs in use site wide is maintained by Industrial Hygiene. Each MSDS must be in English and contain at least the following information:

(1) Manufacture's information - name, address and telephone number of the chemical manufacturer, importer or other responsible party who can provide additional information on the hazardous chemical.

(2) Hazardous ingredients/identity information - the chemical and common name(s) of the ingredient(s) which contribute to the known hazards and the common name(s) of the mixture itself.

(3) Physical/chemical characteristics of the material - such as liquid, solid, or gas, color, corrosivity and reactivity.

(4) Fire and explosion hazard information - such as vapor pressure, flash point.

(5) The primary route(s) of entry into the body.

(6) Health hazard data - the health hazards of the hazardous chemical, including signs and symptoms of exposure, and any medical conditions which are generally recognized as being aggravated by exposure to the chemical.

(7) The OSHA permissible exposure limit, ACGIH Threshold Limit Value, and any other exposure limit used or recommended by the chemical manufacturer, importer, or employer preparing the MSDS.

(8) Whether the hazardous chemical is carcinogenic or potentially carcinogenic based on various reports.

(9) Precautions for safe handling and use - Any generally applicable precautions for safe handling and use which are known, including appropriate hygienic practices, protective measures during repair and maintenance of contaminated equipment, and procedures for clean-up of spills and leaks.

(10) Emergency and first aid procedures

(11) Control measures - Any generally applicable control measures which are known such as appropriate engineering controls, work practices, or personal protective equipment..

(12) Date of preparation of the MSDS

Some information from an MSDS is transcribed to a hazard warning label. All containers with hazardous chemicals must be labeled at Rocky Flats. Typically, the label is provided by the manufacturer. If for some reason a container doesn't have a manufacturer's warning label, one will be affixed locally.

The NFPA 704 M, Hazard Identification System is used at Rocky Flats. This system consists of diamond shaped warning labels which provide hazard information using a color and number scheme. Health information is contained in a blue field, flammability in red, reactivity in yellow, and any special hazards in white. A number between 0 and 4 is placed in the blue, yellow, and read fields; text is usually used in the white field. 0 indicates no significant hazard in that particular category, while 4 indicates an extreme hazard.

Thus, general hazard information is provided by a hazard warning label. If a worker needs additional information, they may refer to an MSDS.

c. Define a carcinogen and provide examples of carcinogens.

A carcinogen is any material which, based on scientifically evaluated evidence, can cause cancer in man or animals. Epidemiological and toxicological studies, case histories from clinical records, and studies of chemical structure are used by government agencies to evaluate the carcinogenic potentials of materials. Examples of carcinogens are: arsenic, asbestos, benzene, carbon tetrachloride, formaldehyde, and vinyl chloride.

***d. Discuss the key elements of a Carcinogen Control Program including specifically carcinogenic chemicals and asbestos control*.**

The carcinogen/asbestos control program establishes the requirements to identify, evaluate, and control occupational exposures to chemical carcinogens. The program is designed to maintain occupational exposure As Low As Reasonably Achievable (ALARA). Key elements of the program include:

(1) An Occupational Safety Analysis (OSA) must be written describing the use of a carcinogen, the procedures controlling it's use, and emergency actions for all regulated areas.

(2) "Regulated" areas must be established where carcinogens are used.

(3) Records must be maintained for all personnel working in regulated areas. The records become part of the employee's medical file.

(4) Signs warning of the presence of carcinogens must be posted at all entrances to regulated areas.

(5) Inventories of carcinogens shall be maintained and reviewed periodically.

(6) Employees must be trained to work with carcinogens.

e. Discuss the importance of facility sanitation and housekeeping programs.

The housekeeping and sanitation program at Rocky Flats is controlled by Health and Safety Practices (HSP) Manual section 13.08. One of the purposes of a housekeeping program is to limit a facility's combustible loading. By doing so, we can either prevent the occurrence of a facility fire or at least mitigate the consequences of a fire. Good housekeeping practices are also important in reducing "trip and fall" hazards, reducing airborne dust and other potential respiratory irritants, and reducing the hazard from falling objects. Sanitation is important because it can affect the health of employees. In an unsanitary facility, the potential for the spread of disease is significantly increased.

f. Discuss the importance and types of equipment used for personnel protection and safety including:

Eye Protection - HSP 7.01, Eye and Face Protection, discusses the eye protection program at Rocky Flats. Eye and face protection requirements for work activities are determined by the job supervisor with assistance from Occupational Safety and Industrial Hygiene. All personnel are required to obey posted eye protection requirements. HSP 7.01 describes four types of eye protection:

(1) Class I Eye Protection. Safety glasses which meet the requirements of ANSI Standard Z87.1 and provide basic protection against impact particles and innocuous sprays are Class I. Glasses and frames with side shields are the most common eye protection used at Rocky Flats.

(2) Class II Eye Protection. Class II provides additional eye and face protection from impact particles. Class II protection consists of safety glasses with side shields worn below a full face shield.

(3) Class III Eye Protection. Class III provides eye and face protection against chemical dusts, liquids, and gases. Class III protection consists of chemical goggles worn below a full face shield.

(4) Class IV Eye Protection. This final class of equipment provides eye and face protection against special hazards encountered with furnace operations, welding, glasswork, laser operations, etc.

Foot Protection - HSP 7.02 covers the Rocky Flats occupational foot protection program. Essentially, all occupational protective footwear must comply with the provisions of ANSI Z41.1. There are three classes of footwear:

(1) Protective footwear worn in most industrial locations, construction sites, warehouses, and shop areas are fiberglass toe occupational protective footwear rated at “75”, as a minimum, for compression and impact.

(2) For soil compacting (tamping) and jack hammer operations, employees must use metatarsal guarding over safety shoes.

(3) Finally, if any unique hazards are identified for an activity, the supervisor and Occupational Safety will determine the need for specialized protective footwear.

Ear Protection - HSP 7.06, Hearing Conservation, defines some basic requirements such as:

(1) the need for Industrial Hygiene to maintain a hearing conservation program. The program consists of

- workplace monitoring for noise.
- audiometric testing for employees who work in high noise areas.
- providing hearing protection equipment to employees.
- record keeping.
- training.

(2) the need to post high noise areas appropriately and control access to such areas. Personnel shall not be allowed to enter high noise areas without:

- appropriate hearing protection.

- training in hearing conservation procedures.

- having a current (within 12 months) audiogram if entering a high noise area is routine.

Protective Clothing - Proper protective clothing is required whenever hazards of processes or environment, chemical hazards, radiological hazards, or mechanical irritants encountered are capable of causing injury or impairment in the function of any part of the body through absorption, inhalation or physical contact. The type of protective clothing to be used is based on the type of environment and hazards associated with the hazard. At Rocky Flats, the primary protective clothing used are coveralls, Tyveks, and Supplied Breathing Air garments for radiological protection.

Head Protection - HSP 7.07 provides guidance on occupational head protection at Rocky Flats. Head protection requirements for work activities are determined by the job supervisor with assistance from Occupational Safety and Industrial Hygiene. All personnel are required to obey posted head protection requirements. The primary head protection device is a helmet. Helmets must comply to ANSI Z89.1-1986. The following types and classes of helmets are described below:

Type 1: Helmets with brim.

Type 2: No brim but may include a peak.

Class A: Intended to reduce the force of impact of falling objects and to reduce the danger of contact with exposed low-voltage conductors.

Class B: Intended to reduce the force of impact of falling objects and to reduce the danger of contact with exposed high-voltage conductors.

Class C: Intended to reduce the force of impact of falling objects. This class offers no electrical protection.

Respiratory Protection - HSP 7.03 provides instructions for the use of respiratory protection at Rocky Flats. Engineering controls are to be used as the primary method of minimizing airborne radioactivity and chemical or biological exposure to workers. Administrative controls, including access restrictions and the use of specific work practices, are to be used as the secondary method to minimize worker exposure. When engineering and administrative controls have been applied and the potential for airborne exposure still exists, respiratory protection should be used to limit exposures.

The two primary methods of respiratory protection at Rocky Flats are the full face respirator and the Supplied Breathing Air (SBA) suits. Respiratory requirements for specific jobs are determined by both the nature of the hazard involved (which could be unknown, particulate, gas/vapor, carcinogen, etc.) and the work place conditions (high temperature, confined space, etc.). Naturally, workers must be trained and qualified to use the prescribed protection. Additionally, workers must be fitted for the equipment to ensure the equipment functions properly.

HSP 7.03 contains a multitude of requirements and programmatic detail. At this general of a level of discussion, it is sufficient to know that workers will receive appropriate training (usually Radiation Worker II if you need a full face respirator), be "fit" for the necessary protective equipment, and be evaluated as medically qualified to wear such equipment.

5.6 Using the Department of Energy Hoisting and Rigging Manual, personnel shall demonstrate knowledge of the principles of material handling, hoisting and rigging necessary to identify safe/unsafe work practices.

Prior to discussing any of the following, one needs to know that there are three DOE-specified categories of lifts: ordinary, pre-engineered production, and critical. A pre-engineered production lift is a repetitive lifting operation that is independent of the nature of the load to be lifted. A critical lift is defined in 5.6.d below. If a lift is neither critical nor pre-engineered production, it is said to be ordinary. An ordinary lift is considered a "traditional" hoisting and rigging activity. All lifts must meet the requirements specified for ordinary lifts.

a. Describe management's responsibility and accountability with regards to hoisting and rigging.

Management must establish and implement a program consistent with the requirements of DOE-HDBK-1090-95, Hoisting and Rigging.

Hoisting and rigging operations for ordinary lifts and for pre-engineered production lifts requiring more than one person require a "designated leader." This individual shall be present at the lift site during the entire lift operation. Their responsibilities are:

(1) ensure that personnel involved in the lift understand how the lift is to be made.

(2) ensure that the weight of the load has been determined and does not exceed the capacity of the equipment.

(3) survey the site for hazardous or unsafe conditions.

(4) ensure the equipment is properly set up.

(5) ensure that a "signaler" is assigned, if required.

(6) direct the lifting operation to ensure it is done safely and efficiently.

(7) stop the job when an unsafe condition is recognized.

(8) direct operations if an accident or injury occurs.

For critical lifts, the above requirements apply, but the "designated leader" is referred to as "Person-in-Charge (PIC)." The PIC has additional responsibilities. Specifically, they must ensure that a pre-job plan or procedure is prepared that defines the entire operation and includes:

(1) identification of items to be moved, including size, weight, center of gravity, and hazardous or toxic characteristics.

(2) identification of equipment by type and capacity.

(3) detailed rigging sketches to include load vectors, lifting points, sling angles, boom and swing angles, methods of attachment, and crane operations.

(4) operating procedures which include rigging precautions and safety measures as appropriate.

***b. Discuss operating practices for hoisting and rigging operations*.**

DOE-HDBK-1090-95 provides numerous requirements for hoist operations. Summarizing, the handbook discusses:

(1) conduct of the operator. The operator shall be physically and mentally fit as well as being qualified on the equipment. Specific direction not to operate out-of-service equipment and not to violate lockout/tagouts is also given.

(2) size of load. The requirement to know the weight of a load and the capacity of equipment is reiterated.

(3) attaching the load. The discussion centers on using approved devices.

(4) moving the load. Precautions such as the following are prescribed:

- before starting the hoist, be certain all personnel are clear of equipment.

- do not operate hoists until the hook is positioned above the center of gravity of the load.

- avoid carrying loads above personnel.

- avoid unnecessary starts and stops.

- if power is lost during operation, place all controllers in the OFF position.

- do not leave a suspended load unattended.

- obey a STOP signal regardless of who gives it.

DOE-HDBK-1090-95 provides the following requirements for rigging hook operations. Operators must:

(1) determine that the load or force required does not exceed the rated capacity of the hook's assembly, taking into account special conditions such as choking or grabbing.

(2) avoid shock loading.

(3) keep hands, fingers, and body from getting between the hook and the load.

c. Describe good and bad rigging practices.

Figure 12-1, Good and Bad Rigging Practices, from DOE-HDBK-1090-95 is shown below to illustrate good and bad rigging practices.

d. Define critical lifts.

A lift shall be designated as critical if collision, upset, or dropping could result in any of the following:

(1) unacceptable risk of personnel injury or significant adverse health impact.

(2) significant release of radioactive or other hazardous material or other undesirable conditions.

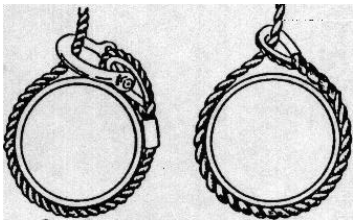
(3) undetectable damage that would jeopardize future operations or the safety of a facility.

(4) damage that would result in unacceptable delay to schedule or other significant program impact such as loss of vital data.

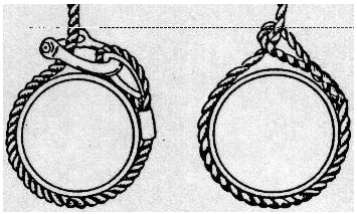
A lift should also be designated as critical if the load requires special care in handling because of size, weight, close-tolerance installation, high susceptibility to damage, or other unusual factors.

Good and Bad Rigging Practices

Use of Chokers



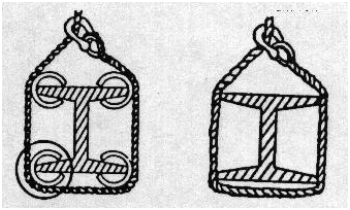
Good - No cutting action on running lines



Bad - Bolt on running line can work loose

Bad - Because of cutting action of eye splice on running line

Suspending Needle Beams or Scaffolds

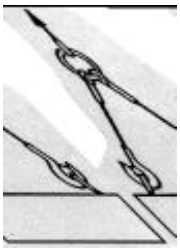


Good - Sharp corners padded

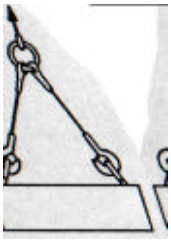
Bad - Steel can cut rope

Hook Slings

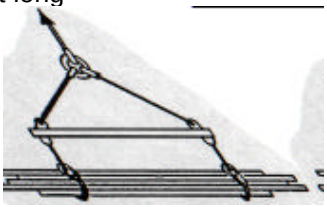
Good - Hooks are turned out



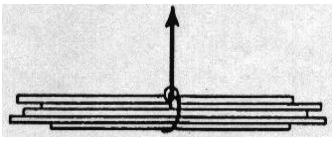
Bad - Hook openings are turned in



Double slings shall be used when hoisting two or more pieces of material over 12 ft long



Right - Load over 12 ft long

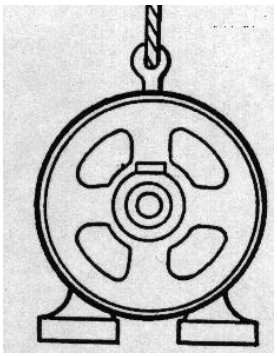


Wrong - Load over 12 ft long

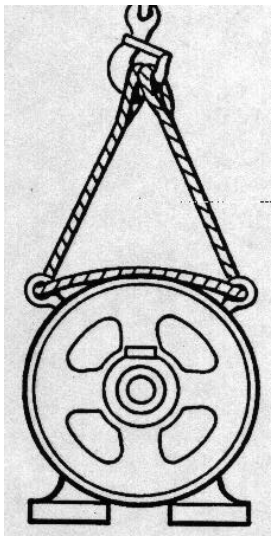
Figure 12-1. Good and bad rigging practices.

Good and Bad Rigging Practices

Eyebolts

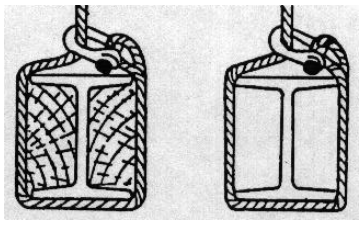


Good practice - vertical lift on eyebolt



Bad practice - lifting on eye-bolts from an angle reduces safe loads as much as 90%

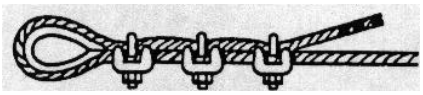
Hoisting Structural Steel



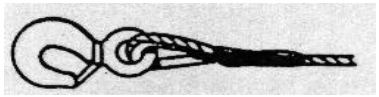
Good - Use space blocks and pad corners

Bad - Can bend flanges and cut rope

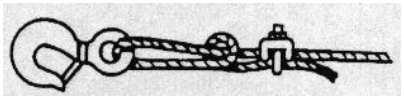
Eye Splices



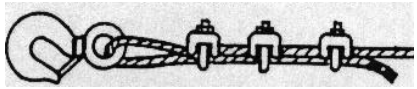
Good practice - Note use of thimble in eye splice



Good practice - Use of thimble in eye splice



Bad practice - Wire rope knot with clip. Efficiency 50% or less



Bad practice - Thimble should be used to increase strength of eye and reduce wear on rope

Figure 12-1. (continued).

SECTION 6: CONDUCT OF OPERATIONS

6.1 Personnel shall demonstrate knowledge of the principles of Conduct of Operations and relate these principles to an operational environment.

a. Referring to a copy of DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities, (including Attachment 1) locate applicable guidelines and requirements for specific activities.

DOE Order 5480.19 is a broad-reaching document which provides guidelines and/or requirements for numerous activities. Examples of specific activities which are discussed in DOE Order 5480.19 are listed below along with the section of the order where they are discussed. Additional site specific documents may also discuss activities included in DOE Order 5480.19. This list is not all inclusive.

Specific Activity	DOE Order 5480.19 Location	Other Documents
Operator Inspection Tours	Chapter II, Section C.3	1-31000-COOP-012
Repeating Back Verbal Instructions	Chapter IV, Section B & Section C.6	1-31000-COOP-015
Required Reading	Chapter XIV	1-31000-COOP-015
Logkeeping Corrections	Chapter XI, Section C.5	1-31000-COOP-006
Lockouts and Tagouts	Chapter IX	1-15320-HSP-2.08

b. For each of the eighteen chapters in Attachment 1 to the DOE Order 5480.19, explain how each chapter contributes to an effective and safe operational environment.

Chapter 1 - Operations Organization and Administration

This chapter describes the administrative controls and practices that, when implemented fully, result in an effective and safe operational environment. Beginning with DOE facility policies that describe the philosophy of standards of excellence under which the facility is operated and establish clear lines of responsibility for normal and emergency conditions, other principles are suggested for the control of operations. These are: establishing written standards for operations, providing adequate resources to permit effective implementation, periodically monitoring and assessing performance, and holding personnel accountable for their performance.

These administrative controls put into place a system whereby operational effectiveness and safety can be measured and analyzed. The development and implementation of corrective actions follows. Continuous improvement in

efficiency and safety is thus achieved in accordance with total quality management principles.

Chapter 2 - Shift Routines and Operating Practices

This chapter describes some important aspects of routine shift activities and watchstanding practices that promote the professional conduct of operations personnel and result in meeting DOE and facility management expectations for operator performance. Professional conduct and good watchstanding practices result in appropriate attention to facility conditions, a necessary part of maintaining a safe and effective operational environment. Key elements are: effective equipment monitoring to detect abnormal conditions or adverse trends, notifying supervisors promptly of unusual or unexpected situations, understanding equipment status and operational authority, and following proper industrial safety, radiological protection (if applicable) and quality assurance practices.

The chapter specifically provides guidelines for status practices, safety practices, operator inspection tours, use of round/tour inspection sheets, personnel protection, response to indications, resetting protective devices, load changes, authority to operate equipment, shift operating bases, and potentially distractive written material and devices.

Chapter 3 - Control Area Activities

This chapter recognizes the control area or control room as the most critical facility operating base and the coordination point for all important facility activities. It stresses principles involving limited control area access, professional behavior of personnel in the control area, monitoring of main control panels, control operator ancillary duties, and operation of control area equipment. Errors and unnoticed equipment problems if formality and attention to detail is not practiced by operators in the control room.

Chapter 4 - Communications

This chapter describes the important aspects of a plant program for audible communications and emphasizes that accurate communications are essential for the safe and efficient operation of facilities. Audible communications are used to transmit operating and emergency information within the facility. Examples are oral (face-to-face), telephone, radio, public address (page) announcements, sound powered phones, and special sounds (horns and bells). Guidance provided includes the practice of repeating back instructions to ensure accurate transmission and receipt of verbal instructions, use of standardized terminology, and use of a phonetic alphabet. Inadequate communication is a common root cause behind operator error. On the softer side, personnel morale, which can indirectly affect facility efficiency and safety (consider incidents of sabotage, equipment tampering, and malicious compliance), depends on open, honest and clear communications.

Chapter 5 - Control of On-Shift Training

The guidelines of this chapter relate to control of training activities by operations personnel. On-shift training should be conducted so that the trainee satisfactorily completes all of the required training objectives and receives maximum learning benefit from this experience without unduly affecting normal operations. Facility operation by personnel under instruction should be carefully supervised and controlled to avoid mistakes in operations by unqualified personnel and to use trainee's time effectively. These controls are therefore necessary to maintain safe and efficient operation of the facility during the conduct of hands-on training. The following are key elements: adherence to formal training programs, use of instructors that are qualified themselves on the subject equipment, supervision and control of trainees by qualified operators, operator qualification program approval, formal training documentation, suspension of training during abnormal or accident conditions, and establishing a maximum number of trainees at one time.

Chapter 6 - Investigation of Abnormal Events

This chapter covers important aspects of the abnormal event investigation program. Abnormal events do occur and when they do, they often cause an impact on the safe and efficient operation of the affected facilities. Therefore a program for the investigation of abnormal events should ensure that facility events are thoroughly investigated to assess the impact of the event, to determine the root cause of the event, to ascertain whether the event is reportable to DOE (per DOE 232.1) and to identify corrective actions to prevent recurrence of the event. As future events are prevented through successful implementation of this program, the safe and efficient operation of the facility is improved.

Chapter 7 - Notification

This chapter provides guidelines to ensure uniformity, efficiency, and thoroughness of notifications that support fulfillment of DOE requirements consistent with DOE 232.1. Proper notifications of abnormal or unusual events contributes to safe and efficient operation of the facility in a couple of ways. The first is that the notification results in the involvement of a larger pool of people whose knowledge can help stabilize and resolve the immediate situation at hand. The second is that being trained to follow a rigorous notification process ensures that vital information, needed to analyze and prevent future recurrence, is not overlooked.

Chapter 8 - Control of Equipment and System Status

This chapter provides an overall perspective on control of equipment and system status. Control of equipment and system status contributes to safe and efficient facility operations by ensuring that an adequate "safety envelope" exists to authorize and perform work. A facility's safety envelope is defined by the

proper operation and configuration of a set of equipment considered vital to a safe operating environment. This equipment is termed “vital safety equipment.” If a piece of equipment fails or is shut down for maintenance, this fact needs to be recorded so that affected operations can be terminated or prevented until the equipment or system is restored. In the case where redundant equipment exists that could be operated to maintain the safety envelope for continued operations, its status must be known in order for it to be relied upon. Temporary modifications must also be tracked for the same reasons.

Chapter 9 - Lockouts and Tagouts

This chapter describes the important elements of a Lockout/Tagout Program and is intended to meet the requirements of 29 CFR 1910. A safe and efficient operational environment is maintained by providing a method for equipment status control through component tagging or locking which should protect personnel from injury, protect equipment from damage, maintain operability of plant systems, and maintain the integrity of the physical boundaries of plant systems. Appropriate and proper use of tags and locks prevents inadvertent operation of equipment when there is a potential for equipment damage or personnel injury during equipment operation, servicing, maintenance, or modification activities.

Chapter 10 - Independent Verification

This chapter describes the important aspects of an independent verification program which when implemented should provide a high degree of reliability in ensuring the correct facility operation and the correct position of components such as valves, switches, and circuit breakers. This is important to the safe and efficient operation of a facility because independent verification recognizes the human element of component operation; that is, any operator, no matter how proficient, can make a mistake. Thus when mistakes are found and corrected before an operation takes place, safety and efficiency are improved.

Chapter 11 - Logkeeping

This chapter describes the features needed in the operation logs to ensure they are properly maintained. Operations logs should be established for all key shift positions and should contain a narrative of the facility’s status and all events as required to provide an accurate history of facility operations. Proper logkeeping is essential to the safe and efficient operation of a facility because it provides the data necessary for the reconstruction of abnormal or unusual events. When the data is properly analyzed and corrective actions are taken, subsequent recurrence of the event should be prevented. Logkeeping also promotes personal accountability and improved communication of information about the facility’s status among operating personnel.

Chapter 12 - Operations Turnover

This chapter describes the important aspects of a good shift turnover. The comprehensive transfer of information pertinent to the operation of the facility is vital to safe and efficient operations, as evidenced by a historically high error rate associated with poor shift turnovers resulting from improper reviews of logs, unclear communications and neglecting to discuss key operating parameters and status. Safe operations also depend on operating personnel being fit for duty. Therefore, it is also the responsibility of the off-going person to determine this by looking for evidence of sickness with corresponding degradation of mental or physical ability to do the job due to the sickness itself and/or the effects of medication the person might be taking. Other compromising conditions such as drug and alcohol abuse should also be considered among the things to look for.

Chapter 13 - Operations Aspects of Facility Chemistry and Unique Processes

This chapter describes the important aspects of operations involving chemistry and unique processes and their relationship to safe and efficient facility operation. Operational monitoring of facility chemistry or unique process data and parameters should ensure that parameters are properly maintained. Proper monitoring will identify problems before components or safety are adversely affected. Operating personnel must be knowledgeable about the chemicals and processes they are working with and depending upon so that they can detect and correct off-normal parameters in a timely manner.

Chapter 14 - Required Reading

This chapter describes an effective required-reading program. Such a program contributes to facility safety and efficiency by ensuring that appropriate individuals are made aware of important information that is related to job assignments. Procedure changes, equipment design changes, related industry and in-house operating experience information, and other information necessary to keep operations department personnel aware of current facility activities are examples of the kind of useful information that should be made available to keep operating personnel current.

Chapter 15 - Timely Orders to Operators

This chapter describes the key features of an effective operator orders program. This contributes to safe and efficient operation by providing a means for communicating current, short-term information and administrative instructions to operations personnel. This becomes necessary to accommodate the changing needs and requirements of DOE facility operations. For example, orders could include instructions on the need for and performance of specific evolutions or tests; it could also include work priorities, announcements of policy

information, and administrative information. Typical information includes special operations, administrative directions, special data-collection requirements, plotting process parameters, and other similar short-term matters.

Chapter 16 - Operations Procedures

This chapter describes the important aspects of operations procedure development and use. Operations procedures should provide appropriate direction to ensure that the facility is operated within its design basis and should be effectively used to support safe operation of the facility. When operations personnel adhere to the policy to follow approved, properly written procedures, their operational performance should be always be consistent and safe.

Chapter 17 - Operator Aid Postings

This chapter describes the important aspects of an operator aid program. Facility operator aids (information posted for personnel use) should provide information useful to operators in performing their duties and thus provide an important function in the safe operation of the facility, provided that they are kept current and do not conflict with any other controlled procedure or information. Examples are copies of procedures (portion or pages thereof), system drawings, handwritten notes, information tags, curves, and graphs.

Chapter 18 - Equipment and Piping Labeling

This chapter describes the important aspects of a labeling program. A well-established and maintained equipment labeling program should help ensure that facility personnel are able to positively identify equipment they operate. It will enhance training effectiveness, help reduce operator and maintenance errors resulting from incorrect identification of equipment, and reduce personnel radiation and other hazardous material exposure as operators spend less time identifying components.

c. Identify the key elements of assessments, surveillances, and audits, and their application.

Assessment Planning - Research and planning prior to each assessment improves efficiency and produces the most effective use of limited assessment time and resources. Assessment planning involves two steps; a pre-assessment information review and the development of an assessment plan.

Initial Observations, Interviews, and Document Reviews - Observation is often the most effective technique used during a performance-based assessment. Observing activities as they are performed, provides information directly related to the effectiveness of operations. Interviews with facility operations personnel are an effective method of determining the level of knowledge and familiarity with facility policies and procedures. In general, document reviews are conducted for three reasons; to gain familiarity with the requirements contained

in facility policies, procedures, etc.; to validate or disprove apparent deviations from requirements and identify programmatic breakdowns or widespread problems; and to investigate apparent inconsistencies between facility policies and procedures and DOE Orders. Applicable documents should be reviewed both prior to and during the assessment.

Pulling The String - Additional Observations, Interviews, and Document Reviews - "Pulling the string" is the process of following up on leads using observations, interviews, and document reviews. A lead is considered a deviation from expectations or an apparent deviation from requirements that is obtained as a result of observations, interviews, or document review. The process should continue until all leads have been validated, programmatic breakdowns or widespread problems are identified, or sufficient evidence exists to disprove the apparent deviation.

Determination and Reporting of Findings and Concerns - The end product of the assessment process is the identification and reporting of findings and concerns. The assessment report provides facility management with areas for improvement, as reported through these concerns. Findings and concerns are defined as follows: a finding is an individual item (observable fact) that does not meet requirements; and a concern is a determination of a programmatic breakdown or wide-spread problem supported by one or more findings which becomes an issue that management must address to prevent recurrence of findings.

d. Describe the self-assessment process.

The same basic process for assessing the contractor or another organization is used for performing self-assessments except that the focus is inward for the purpose of self-improvement per Total Quality Management concepts. Specifically, the process should include: a review of past assessments and actions taken/completed to resolve findings, development of an assessment plan, making observations, conducting interviews, reviewing program documents, pulling the string, and assembling and reporting findings. The following excerpt from DOE 5700.6C describes some principles involved with performing independent (self) assessments:

- A process of planned and periodic independent assessments should be established and implemented by an independent assessment organization. Independent assessments should focus on improving items and processes by emphasizing line organization's achievement of quality.
- Personnel performing independent assessments should act in a management advisory function. Their responsibilities are to monitor work performance, identify abnormal performance and precursors of potential problems, identify opportunities for improvement, report results to a level of management having the authority to effect corrective action, and verify satisfactory resolution of problems.
- Personnel performing independent assessments should be technically knowledgeable and focus on improving the quality of the processes that lead to the

end product.

- Personnel performing independent assessments should not have direct responsibilities in the area they are assessing.
- Independent assessments should be conducted using criteria that describe acceptable work performance and promote improvement.
- Scheduling of assessments and allocation of resources should be based on the status, risk, and complexity of the item or process being assessed. Scheduling should be flexible and additional attention should be given to areas of questionable performance.
- Assessment results should be tracked and resolved by management having responsibility in the area assessed. Follow up review of deficient areas should be initiated as necessary.
- Responses to assessments should include the following, as applicable: action to correct the deficiency; cause identification; actions to prevent recurrence; lessons learned; and actions to be taken for improvement.

e. Referring to actual copies of facility Occurrence Reports, discuss how a lack of proper conduct of operations at DOE facilities has led to improper operational results.

(If you don't have access to the Occurrence Reporting and Processing System (ORPS) database, your mentor or someone in the training and qualification group can assist you in obtaining copies of actual reports.)

f. Referring to a copy of each; DOE Order 430.1 (formerly, 4330.4B), Maintenance Management Program, 232.1 (formerly, 5000.3B), Occurrence Reporting, and 5700.6C, Quality Assurance, explain how each contributes to a proper conduct of operations environment.

<u>DOE 430.1, Maintenance Management Program</u>

This order establishes the requirements for controlling the conduct of maintenance activities. Maintenance work is controlled at the appropriate level by specialized procedures that, when properly written, provide the necessary interface with proper conduct of operations, such as, scheduling work on the Plan of the Day, shift manager approval to commence work, establishing the proper lockout/tagout, updating system status to reflect the activity and unavailability of the equipment. Preventive maintenance also contributes to identifying and correcting potential problems and thus preventing unexpected events from impacting mission operations.

<u>DOE 232.1, Occurrence Reporting</u>

This order provides guidance on what types of events should be reported, how they should be categorized, who should be notified and when for each event

category, and what information about the event should be reported (date, time, category level, facility identification, responsible line manager, nature of

occurrence, description of occurrence, direct and root causes, corrective actions, etc.). The proper conduct of operations depends directly on the prompt identification, notification, analysis and correction of errors and off-normal events. When this becomes a habit for employees, the resulting attention to detail, rigor and formality of their operations is evidence of a healthy conduct of operations environment.

DOE 5700.6C, Quality Assurance

This order provides the guidelines for establishing an effective quality assurance program (QAP). As can be seen from the following, there are many similar attributes that correspond to and support proper conduct of operations.

- organizational structure
- levels of authority
- interfaces
- functional responsibilities
- planning
- training and personnel development
- preparing, reviewing, approving, and verifying designs
- qualifying suppliers
- preparing, reviewing, approving, and issuing instructions and procedures
- verifying supplier work
- identifying and controlling hardware and software
- manufacturing
- managing and operating facilities
- calibrating and controlling measuring and test equipment
- conducting investigations and acquiring data
- performing maintenance, repair, and improvements
- performing assessments
- controlling records

g. Describe the purpose of Safeguards and Security, and the role that it plays with regards to conduct of operations.

The purpose of the Safeguards and Security (S&S) is to account for and protect Special Nuclear Materials (SNM) and classified data from theft or loss. S&S and Conduct of Operations (COOP) are complementary programs. COOP aids S&S by providing a rigorous and formal operating environment that also facilitates the tracking and reporting of events that fall into the S&S arena. S&S contributes to COOP by providing multiple levels of protection against terrorist attack or sabotage which often is aimed at compromising the safety systems of a facility and certainly endangers the health and safety of facility personnel.

h. Discuss proper critique principles and describe a proper critique process, including key elements.

The purpose of critiques is to assemble all of the facts about an event or operation. It is not to assign blame or be used as a basis to administer disciplinary action against an involved employee. Employees must feel free to provide factual information without fear of retribution and this must be communicated to them and practiced consistently by management in order for a cultural environment to exist that will support an effective critique process. Otherwise, information will be concealed that may be key to preventing recurrence of the event. For specific information concerning local implementation at RFETS, refer to the Rocky Flats Plant Administrative Procedures Manual. The principles and elements of a good critique process are as follows:

1. Both off-normal events and successes are critiqued. The critique of off-normal events provides the basis for understanding why something went wrong and how to prevent its recurrence. The critique of successes is important because we want to be able to repeat the success and we may find ways of improving upon the success at the same time.
2. The designation of who calls and conducts the critique meeting(s) is important to obtaining the facts in a complete and impartial manner. It may be necessary to assign a leader who was not involved in the event to prevent prejudice or inappropriate influence of the outcome.
3. A critique is a formal meeting. It may consist of several meetings with a combination of personnel.
4. All who can contribute factual information should attend the critique meeting(s).
5. The DOE Facility Representative should be notified of each critique meeting and invited to attend.
6. Critique meetings should, with few exceptions, be held as soon as the situation is stable. In any event, they are held before the involved people leave for the day (if possible - there are cases when an event is not discovered until sometime after those involved have gone home and they may get called back in or those discovering the event may not know immediately everyone who might have factual knowledge).
7. Initial categorization and notification for DOE 232.1 is made before or concurrently with the critique meeting. DOE 232.1 requires this to be done within 2 hours of discovery of the event’s happening.
8. A form is provided in the administrative procedure to be “filled-in” for the personal statements that are made by involved personnel.

9. Before a critique convenes, the leader determines if personal statements are necessary. If they are, the leader will distribute forms to the appropriate people.
10. When personal statements are required of key personnel involved with the event, they are encouraged to write what they did, saw, heard, etc.
11. The statements, if desired are preferably prepared before the critique meeting starts and before the principal, involved people get together to discuss the event (collaboration of the people involved greatly reduces the value of the statements).
12. Personal statements are signed and dated.
13. Completed personal statements are provided to the leader at the critique meeting. They are attached to the meeting minutes and become part of the official record.
14. Formal meeting minutes are recorded. Facts shall be listed in chronological order. Tape recorders, stenographers, etc., are used to help document the minutes.
15. Critique minutes are signed by the leader and all contributors.
16. A pre-designed form helps to guide the leader through the critique process. It provides the line of questioning and includes places for the pertinent information. The form is provided in the administrative procedure.
17. Critique minutes serve as the record of what happened for simple events, and the foundation for any subsequent investigation, if warranted, for more complex events.
18. Categorization and/or notification may be changed when the critique is completed.
19. Critique minutes facilitate the assigning of corrective action(s) and provide the basis from which root cause and recurrence control can be determined.
20. Critique reports are distributed within the facility, to other selected facilities, to DOE, and to a central organization for the purposes of further distribution and analysis.
21. Persons designated as critique leaders are formally trained for the task, and have passed a written test and an oral examination.
22. The critique leader must endeavor to fully understand the details, corroborate the facts, challenge assumptions and be aware of what hasn't been established (looks for holes, missing information).

I. Define root cause, and explain its importance to operational safety.

The root cause is defined as the most basic reason(s) for, or the fundamental cause of an event; which if corrected, will prevent recurrence. Operational

failures of all kinds (operator error, component failure, management system failure, procedural error, etc.) challenge the safety environment of a facility. Therefore any reduction in the incident rate and/or the severity of off-normal events will result in an overall improvement of safety for both the workers and

the public at large. Correctly identifying the root cause with corresponding corrective actions has the direct effect of achieving such a reduction. Of course this is what should happen in an ideal world. In practice, the fiscal restraints of today make it difficult to always implement the corrective action that is needed to maintain or improve upon the status quo. Since we value safety above all else, this then forces us to become more innovative in our approach to correct for root causes as well as drive us to conclude that a more fundamental cause may still exist (e.g., a management system that wastes dollars, imposition of unnecessary requirements, etc.) that must be corrected first.

j. Define and describe what Lessons Learned are, and explain their importance to operational safety.

Lessons Learned are bulletins that contain related industry (e.g., NRC, commercial nuclear, etc.) and in-house (i.e., within DOE) operating experience information that may be of interest to operating personnel and management with respect to preventing off-normal events and/or improving operational efficiency. They come from a variety of sources such as the Occurrence Reporting and Processing System database, the Weekly Operating Experience Summary from the DOE Office of Nuclear Safety, and Government-Industry Data Exchange Program on-line information retrieval. Lessons Learned information contributes to operational safety by preventing future similar operational events from occurring, improving techniques for performing operations such that a risk reduction occurs, and improving management control systems that affect safety to make them more comprehensive or to correct deficiencies.

k. Describe Stop Work Authority, and your role in its application.

Section H.14, Shutdown Authorization, of the DOE RFFO contract with Kaiser-Hill (DE-AC34-95RF00825) provides guidance regarding “stop work authority”. Portions of this section of the contract are provided below:

“In the event of an imminent health and safety hazard, identified by facility line management or operators or facility health and safety personnel overviewing facility operations, the individual or group that identified the imminent hazard situation should immediately take actions to eliminate or mitigate the hazard (i.e., by directing the operator/implementer of the activity or process causing the imminent hazard to stop work, or by initiating emergency response actions or other actions) to protect the health and safety of the workers and the public and to protect DOE facilities and the environment. In the event an imminent health and safety hazard is identified, the individual or group that identified the hazard should coordinate with an appropriate contractor official, who will direct the shutdown or other actions, as required. Such mitigating actions should subsequently be coordinated with the responsible DOE Field Office Manager, the facility/site DOE management, and the facility/site contractor management. The suspension or stop work order should be promptly confirmed in writing from the cognizant Contracting Officer.”

"Imminent Health and Safety Hazard is a given condition or situation which, if not immediately corrected, could result in a serious injury or death, including exposure to radiation and toxic/hazardous chemicals."

l. Describe the Cost Plus Award Fee process, and the role that it plays in the management of Department facilities.

The Cost Plus Award Fee process no longer applies to RFETS but is similar to the incentive fee provisions of the performance-based contract that we have with Kaiser-Hill. For Maintenance and Operating (M&O) type of contracts, the contractor is given funds for operating expenses plus a percentage of an award fee that represents profit to the contractor. Usually a minimum percentage, such as 50%, is guaranteed regardless of performance quality. The remaining percentage is "earned" by satisfying performance objectives that are negotiated at the beginning of the rating period. The DOE person responsible for evaluating the contractor against the established performance objective(s) is called a performance monitor. Input from all of the performance monitors is collected at the end of the rating period (usually quarterly) by the contracting officer, who then determines the percentage of remaining fee that is awarded to the contractor. The performance-based type of contract RFFO currently has with Kaiser-Hill works a little differently by establishing Performance Measures (PM) at the beginning of the fiscal year that have a percentage of a total available incentive fee associated with each of them. PM's are intended to be used for critical work items and may have "stretch goals" that are outside what would normally be expected to be achievable. In addition to incentive fee, the Kaiser-Hill contract has provision for keeping a percentage (35%) of significant cost savings to the government that they achieve within the first two years through improved business practices and elimination of wasteful, unnecessary spending.

m. State the purpose of the Occurrence Reporting system and process.

The Occurrence Reporting and Processing System (ORPS) is DOE's centralized operational data base that contains all of the unclassified Occurrence Reports that are submitted by facility managers throughout the DOE complex per DOE 232.1. Besides being a computer-based repository of operational data, its purpose is to supply information to all departmental elements and contractors for the use in analyzing trends and developing lessons learned. Information about a significant operational event at one site may help another site prevent the occurrence of a similar type of event. For example, a premature failure of a certain component at a particular site could lead other sites to evaluate if they also have the same component and if so, to take steps to replace it with a more reliable component before failure. Analysis of trends can lead to corrective actions which may correct a systemic problem and prevent multiple future occurrences which when analyzed on their own, may not indicate a systemic problem.

n. Describe the key elements that determine the safety significance of a condition.

A “condition” is defined by DOE 232.1 as any as-found state, whether or not resulting from an event, which may have adverse safety, health, quality assurance, security, operational or environmental implications; and that is more programmatic in nature, for example, an error in analysis or calculation; an anomaly associated with design or performance; or an item indicating a weakness in the management process are all conditions. The operational conditions (referred to as Limiting Conditions for Operation (LCOs)), required to be maintained to provide a “safe” facility environment, are defined in the facilities Final Safety Analysis Report (FSAR). A condition that has safety significance therefore has some degree of potential for challenging one or more of these LCOs. Also any condition, besides those addressed by the FSAR, that could adversely affect the health and safety of workers in the facility would have safety significance. The components of Probable Risk Assessment, probability of occurrence and consequence, apply to determining the level of significance. Examples of conditions that have safety significance are:

- Degraded or failed Vital Safety System Equipment (ventilation, fire suppression/detection, criticality detection and alarm, emergency power, etc.)
- Improperly stored or leaking hazardous materials (radioactive and chemical)
- Poor housekeeping (fire hazard, tripping hazard, etc.)
- Improperly trained personnel
- Poorly written or maintained operational procedures
- Failure to perform surveillances required by the FSAR in a competent and/or timely manner.

o. Describe the key elements of a Lockout and Tagout system.

The components of a Lockout and Tagout system are:

1. Program - A Lockout/Tagout program should be established consisting of policies, procedures to control potentially hazardous energy and materials, and personnel training. This program should ensure that potentially hazardous energy or toxic material sources are isolated and rendered inoperative during servicing or maintenance or in any case where unexpected energizing, startup, or release of stored energy or toxic material can cause injury.

2. Procedure(s) - At RFETS the lockout and tagout procedure is located in the Health and Safety Practices (HSP) manual, chapter 2.08. In addition the identification for what needs to be locked and/or tagged out and any necessary operating instructions for preparing the affected system or

component for shutdown in a safe manner should be present in the maintenance work procedure. The conduct of operations principle of independent verification (a second qualified individual performing a separate and independent check of an item such as a valve position, tag or lock installation, breaker position, system parameter, etc.) should be applied to the written procedures as well as the performance of the procedures to ensure proper system alignment and safe system conditions (depressurized, drained, vented, etc.).

3. Documentation - Lockout and Tagout Forms are used to record what components are being locked and/or tagged and the names and signatures of personnel who authorized, installed and verified the locks and/or tags. The same form is used for documenting the removal of the locks and/or tags. These forms are kept together and indexed in a log book that is maintained by the Lockout/Tagout Manager (LTM) (or shift manager in an emergency when the LTM is not available) for the facility.

4. Locking and Tagging Devices - These are locks, tags, chains, wedges, key blocks, adapter pins, self-locking fasteners, or other hardware that is used for isolating, securing, or blocking machines or equipment from energy sources.

5. Periodic Inspections - Periodic inspections should be conducted and documented by authorized personnel, supervisor, or appropriate manager (usually the LTM), to determine whether procedures are being followed and to correct any deviations or inadequacies observed.

6. Training - Training should be provided and documented to ensure that the purpose and function of the Lockout/Tagout program is understood by all personnel and that they have the knowledge and skills required for safe application, use, and removal of Lockouts and Tagouts. Only qualified personnel should be authorized to accomplish a Lockout and/or Tagout.

7. Notification of Personnel - A supervisor or appropriate manager (in most cases, this will be the LTM) should notify affected personnel of the application and removal of Lockout/Tagout devices. Notification should be given before the devices are applied and after they are removed.

References:

1. U.S. Department of Energy, *Operations Assessment Field Handbook*, (Washington, DC: U.S. DOE Office of Operations Assessment, EM-25, 1994).
2. Rocky Flats Environmental Technology Site, *Conduct of Operations Manual*, (Golden, CO: EG&G Rocky Flats, Inc., 1994)
3. U.S. Department of Energy, *DOE Order 5480.19, Conduct of Operations Requirements for DOE Facilities*, (Washington, DC: U.S. DOE, 1992).

SECTION 7: NUCLEAR SAFETY DOCUMENTS AND EVALUATION

7.1 Personnel shall demonstrate knowledge of basic nuclear safety documents and nuclear safety evaluation principles, methods and tools.

a. Identify and describe the types of Hazard Classifications and how they are established/determined.

The DOE currently uses a four category classification system which is discussed in DOE-STD-1027, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports. As part of a facility's preliminary hazard assessment, required to be performed for all facilities, a facility is categorized as hazard category 1, hazard category 2, hazard category 3, or other. DOE-STD-1027 contains flow charts which are used for a classification determination, but the strict definitions of the categories are fairly straight forward. The common element of all definitions is the idea of material at risk.

Other. DOE-STD-1027, Attachment 1, Table A.3 (page A-11) is a table entitled "Thresholds for Radionuclides." If a facility contains less than the listed category 3 quantities of radionuclides, it is categorized as other. As a result, the facility is exempt from the requirements of DOE Order 5480.23, Nuclear Safety Analysis Reports. The terms "non-nuclear facility", "not applicable", "below category 3", and "exempt from 5480.23 SAR requirement" are examples of terms used in place of "other" because the term for this category is not explicitly stated in DOE-STD-1027.

Category 3. A facility which meets or exceeds the criteria of the "Thresholds for Radionuclides" table in DOE-STD-1027 is a hazard category 3 facility. From a practical standpoint, this means the facility has the potential for significant localized consequences - i.e., localized releases of materials in quantities which exceed state and federal reporting requirements. Putting meaning to the numbers, the minimum threshold values from such releases result in less than a 10 REM exposure at 30 meters over a 24 hour period. Most low-level waste facilities at Rocky Flats (such as the 750 Pad) are Category 3.

Category 2. Continuing across the DOE-STD-1027 table, threshold values are also provided for classifying a facility as hazard category 2. An unmitigated release of materials at these levels would result in exposures greater than 1 REM 100 meters from the facility. As a result, category 2 is the level at which emergency planning requirements come into play.

A facility will also be classified hazard category 2 if it has the potential for a nuclear criticality accident. ANSI 8.1 provides the minimum theoretical mass requirements to achieve criticality, but at Rocky Flats it is sufficient to know that our Pu facilities and the former experimental criticality mass laboratory (Building 886) are Cat 2.

Category 1. This level is primarily reserved for class A reactors. A class A reactor is defined to be a reactor capable of operating at a steady state power level greater than 20 megawatts. A facility may also be classified as Category 1 if the Program Secretarial Officer (PSO) deems it necessary. In theory, such a designation would be due to the level of off-site emergency planning required to permit operation of the facility. Currently, there are no Cat 1 facilities at Rocky Flats.

b. Discuss the purpose and main topics covered by each of the following safety-related documents.

Design Basis Reports - The design basis report is a hardware oriented document that defines a set of requirements which bound the design for the various structures, systems, and components (SSCs) within a facility. A classic example would be the "design basis earthquake" of a building. The requirement would be the magnitude of the earthquake for which the building is designed to withstand (i.e., maintain structural integrity). This would be a key element in determining "risk" as discussed below.

Other sections of the document address items such as SSC reliability and maintainability, safety significant equipment, and performance criteria such as efficiency.

Hazard Categorization and Accident Analysis (DOE-STD-1027) - DOE-STD-1027 was written to provide guidance for the preparation of hazard categorizations and accident analysis techniques which are required by DOE Order 5480.23. The standard begins with some general comments about the requirements for Safety Analysis Report (SAR) implementation plans and annual updates. From there, the standard focuses on two areas: (1) the hazard categorization methodology (previously discussed in section 7.1, a.) to be applied at all DOE facilities and (2) the accident analysis techniques appropriate for the "graded approach" philosophy.

The accident analysis section provides the first discussion of the "graded approach" which is required to be applied by DOE Order 5480.23. The idea is quite simple, the application can be difficult. The bottom line on graded approach is that for a simple facility, such as Building 664, we can identify and control hazards using less sophisticated analysis techniques and less detailed facility knowledge. The benefit is obvious - less resources will be required to develop a DOE Order 5480.23 SAR for simple, low hazard facilities than SARs for complex, high hazard facilities.

The "graded approach" should not be misinterpreted to imply that simple, low hazard facilities deserve a lower level of safety awareness or diligence than higher-hazard facilities. DOE-STD-1027 makes it clear that regardless of the category of facility, the contractor must maintain and operate each facility safely. The requirements for a low hazard facility will, however, be less burdensome and will be more easily derived.

The level of effort required for a SAR is determined by three factors:

(1) The magnitude of the hazards in the facility. This is determined by the hazard categorization previously discussed.

(2) The complexity of the facility and the safety systems in the facility. "Complexity" includes factors such as engineered vice administrative safety controls. Typically, a facility which relies on personnel to initiate preventive or mitigative actions will require a more extensive accident analysis than a facility that uses automated safety devices. An engineered feature either works or it doesn't; reliance on personnel brings training and procedures into to the calculation as well as a multitude of other human factor elements.

(3) The stage or stages of the facility life cycle. A new facility will be expected to incorporate all new requirements and standards. Each phase of its construction and start-up would be addressed in the SAR. A facility nearing the end of its life will typically have a considerably reduced scope of work from its initial mission. For such a facility, a DOE Order 5480.23 SAR will only need to address the existing mission. Should the mission be extended or changed, a revision to the SAR would be required.

Safety Analysis Report (DOE Order 5480.23) - DOE Order 5480.23 establishes the requirement for contractors to develop safety analyses that establish and evaluate the adequacy of the safety basis in their facilities. A SAR developed in accordance with DOE Order 5480.23 guidelines will document the results of the safety analysis.

DOE Order 5480.23 specifies a number of requirements:

(1) The use of a graded approach for the level of analysis (as discussed in the above STD-1027 section).

(2) The scope and content of the SAR. The SAR is required to address the following topics:

- executive summary.
- applicable statutes, rules, regulations, and DOE Orders.
- site characteristics.
- facility description and operation (including the design basis of principle structures, components, safety systems, engineered safety features, and processes).
- hazard analysis and classification of the facility.
- health and safety criteria.
- radioactive and hazardous material waste management.
- criticality protection.
- radiation protection.
- hazardous material protection.
- analysis of normal, abnormal, and accident conditions - including design basis accidents; risk assessment; consideration of natural and manmade

external events; and an evaluation of the need for beyond-design- basis accidents. (Note: This "accident analysis" section is basically required to consider everything except acts of sabotage. Sabotage and other covert actions are addressed by the facility's security protection program.)

- management, organization, and institutional safety provisions.
- procedures and training.
- human factors.
- initial testing, operational surveillance, and maintenance.
- derivation of Technical Safety Requirements (TSRs).
- operational safety.
- quality assurance.
- emergency preparedness.
- provisions for decontamination and decommissioning.
- applicable facility design codes and standards.

If all of the above topics were adequately addressed in an all inclusive document it would occupy a multitude of storage areas and would be impossible to maintain. To avoid this problem, the SAR typically refers to other documents. For example, a summary discussion of a facility's criticality safety program with reference to specific program documents might be provided in the SAR. As a result, the SAR in and of itself does not constitute the facilities "safety basis" or "authorization basis". The safety basis is the SAR and all documents referenced by the SAR.

(3) The hazard classification for the facility and operations.

(4) Document control requirements.

DOE Order 5480.23 also specifies implementation requirements and dictates the processes for:

(1) The approval of SARs for new facilities.

(2) The preparation and submittal of upgraded SARs for existing facilities.

(3) Periodically updating SARs.

Technical Safety Requirements (DOE Order 5480.22) - DOE Order 5480.22 contains the requirement for contractors to prepare Technical Safety Requirements (TSRs) for DOE nuclear facilities. The Order specifies content, scope and format for TSRs. TSRs are submitted to DOE for approval. In the nuclear reactor world, TSRs are known as Technical Specifications. Prior to the issuance of DOE Order 5480.22, nonreactor nuclear facilities operated under Operational Safety Requirements (OSRs). Most facilities at Rocky Flats are still using OSRs.

TSRs are a set of requirements which define the conditions, boundaries and controls necessary to safely operate a nuclear facility. Compliance with TSRs

will reduce the potential risk to the public and workers from uncontrolled releases of radioactive material or from radiation exposures due to inadvertent criticality.

Unreviewed Safety Questions (DOE Order 5480.21) - The stated purpose of DOE Order 5480.21 is to "set forth the definition and basis for determining the existence of an Unreviewed Safety Question." The practical use of DOE Order 5480.21 is to establish criteria by which an operating contractor may change facilities or operations without obtaining DOE approval.

In an ideal world, every facility or operation is supported by a DOE approved Safety Analysis (a.k.a. authorization basis). The DOE approval signifies that the Department of Energy is accepting the risk associated with operating a facility or process. The contractor is obligated to operate within the "envelope" defined by the Safety Analysis.

DOE Order 5480.21 primarily comes into play when the contractor wants to modify a facility or process or perhaps create a new process such as the Caustic Waste Treatment effort in Building 371. The contractor could modify the SAR and get explicit DOE approval for each and every change, but DOE Order 5480.21 provides a better way to do business. If the proposed change does not increase the overall risk from operating the facility, the change is said to be "bounded" by the previous analysis. Since the overall risk is what DOE accepts, DOE would not have to approve such a change.

The method used to determine whether a new or modified process increases the overall risk is the Unreviewed Safety Question Determination (USQD). The USQD process is discussed in a subsequent section. If the overall risk is not increased, the USQD is said to be "negative" and the contractor can proceed without notifying DOE. If the risk is increased, DOE must be notified and formally accept the increased risk before the contractor can proceed.

Section 10 of DOE Order 5480.21 dictates:

- The requirement for the contractor to develop procedures to implement the USQD process.

- When a USQD is required to be performed. Specifically, a USQD must be performed for:

  -- Temporary or permanent changes to a facility as described in the existing safety analysis.

  -- Temporary or permanent changes to a procedure as described in the existing safety analysis.

  -- Tests or experiments not described in the existing safety analysis.

- When a situation constitutes a USQ. (Positive USQs are discussed in a subsequent section.)

- What the contractor must do upon discovery of an inadequate safety analysis. Basically, they must:

  -- Notify DOE.

  -- Perform a USQD.

  -- Take action to put the facility in a safe condition until an appropriate safety analysis is performed.

- The documentation requirements for the USQD process.

c. Identify the situations that constitute an Unreviewed Safety Question.

The Unreviewed Safety Question (USQ) criteria can be broken down into seven questions. If the answer to any of the seven questions is yes, then a USQ exits.

(1) Could the proposed activity increase the probability of occurrence of an accident previously evaluated in the safety analysis?

(2) Could the proposed activity increase the consequences of an accident previously evaluated in the safety analysis?

(3) Could the proposed activity increase the probability of occurrence of a malfunction of equipment important to safety previously evaluated in the safety analysis?

(4) Could the proposed activity increase the consequences of a malfunction of equipment important to safety previously evaluated in the safety analysis?

(5) Could the proposed activity create the possibility of an accident of a different type than previously evaluated in the safety analysis?

(6) Could the proposed activity create the possibility of a malfunction of equipment important to safety of a different type than previously evaluated in the safety analysis?

(7) Does the proposed activity reduce the margin of safety as defined in the basis for any technical safety requirement?

Essentially all the questions are driving at risk. Although risk isn't defined until the next section, the bottom line is does the activity increase the frequency or consequences of an accident?

d. Define the terms hazard and risk.

A hazard is the existence of anything that could have an adverse effect. In other words, a hazard is the existence of a source of danger which could cause illness, injury, or death to personnel or damage to a facility or the environment. The source of danger could be almost anything - hazardous chemicals, an energy source such as compressed gas, or an operation such as draining tanks which contain solutions of dissolved Plutonium.

Risk is the probability of occurrence, of a hazardous event, and the consequence of the occurrence. Thus, the first step in any accident or risk analysis is the hazard analysis. Once the hazards have been identified, a frequency of occurrence (or probability) is assigned to the hazard. For example, the probability of spilling a four liter bottle of Pu solution while working in a glovebox might be once every hundred handling operations or once a month - a likely event. Similarly, the probability of a facility fire which compromises the exhaust filter plenum might be once every hundred years - an unlikely event. An event is considered credible if the probability of occurrence is equal to or more frequent than once in a million years (10^{-6}/yr.).

After estimating the frequency of the hazard, the consequence is estimated. The consequence of spilling the four liter bottle in a glovebox would be close to zero. On the other hand, the facility fire could result in a significant release of material to the environment and pose serious problems for workers in the immediate areas. The consequence of such an event would be severe. Therefore, the risk from the likely bottle spill would be much less than the risk from the unlikely facility fire. As a result, considerably more resources would be expended to prevent and mitigate the fire than the spill.

e. Identify who is responsible for safety at Department-owned facilities.

The Secretary of Energy has overall responsibility for the safety of DOE facilities. DOE line managers are directly responsible and accountable for the safety of their activities.

7.2 Personnel shall demonstrate knowledge of the Department of Energy Directive System.

a. Define the following terms:

Policy Statement - A policy statement is nothing more than philosophy and "fundamental values." They are the top level in the directives system and all documents under them must be consistent and reflect the philosophy and values set forth by the Secretary of Energy. Since policy statements are always general in nature, their implementation is accomplished through more specific DOE Regulations, Orders, Notices, and Manuals. DOE P 251.1, Directives System is an example of policy statement.

Regulation - DOE Regulations and rules establish enforceable requirements consistent with DOE's authority under law and in accordance with the Administrative Procedures Act. 10 CFR 835, Occupational Radiation Protection is an example of a DOE regulation.

Order - Orders are used to establish management objectives and requirements. Orders assign responsibility all the way from the Secretary of Energy down to the operating contractor. Most of the new "three digit" orders developed as part of the directives reduction effort contain material similar to that found in the old "four digit" orders, however, some of the new orders are much smaller and have a newly developed "manual" to accompany the order. Manuals establish requirements that supplement DOE Orders and provide more instruction about how the provisions of the Order shall be carried out. Because a Manual supplements a particular Order, it must be developed and issued concurrently with the Order and may not introduce requirements that do not directly relate to the Order requirements. DOE O 420.1, Facility Safety is an example of an Order.

Notice - Notices are expedited Orders. The relationship between Notices and Orders is the same as Shift Orders and formal Procedures at Rocky Flats. Notices are generally issued in response to some event (such as an operational accident). They minimize the usual two year development cycle which most Orders must follow. A Notice is issued for immediate or short-term use. Unless they are extended through the issuance of an additional Notice or incorporated into an Order, Notices are applicable for no longer than one year after their issue date. DOE N 251.1, Cancellation of Directives (expiration date 9/25/96) is an example of a notice.

Safety/Implementation Guide - Guides are lower level documents than Orders, Regulations, and Notices. They impose no additional requirements on facilities and are considered non-mandatory documents. Guides are designed to supplement the higher tier documents. The relationship can be illustrated by considering DOE Order 5480.21, Unreviewed Safety Questions. DOE Order 5480.21 sets forth the requirement for contractors to develop procedures to implement the USQ process. Contractors could spend months developing a program that in no way met the intent of requirements which may have been too generic or ambiguous. To help solve a problem before it happens, DOE issues Guides. If a contractor chooses to follow a Guide, they can be assured of meeting the intent of the higher tier documents and having a satisfactory program. The contractor is, however, free to follow any other path they choose, as long as they can demonstrate compliance with the Order, Regulation, or Notice. DOE G 471.2-1, Classified Matter Protection and Control Implementation Guide is an example of a guide.

Technical Standards - Technical Standards consist of both *Adopted Standards* and *DOE Standards* and are non-mandatory criteria managed under the Technical Standards Program to provide guidance to contractors and DOE personnel on acceptable methods for meeting requirements. They may be

incorporated into *Safety/Implementation Guides* by reference and as such remain non-mandatory. When referenced by *DOE Orders* or *Rules* they can become mandatory in the sense that the contractor must either follow the described methodology or else prove that their methodology is equivalent.

Adopted Standards - Adopted Standards are similar to Technical Standards, except that they are not developed nor maintained by DOE. For example, the former DOE Order 5480.24, Nuclear Criticality Safety, contained a multitude of reference to American National Standards Institute (ANSI) publications. ANSI/ANS-8.3-1986, Criticality Accident Alarm System is an example of an adopted standard.

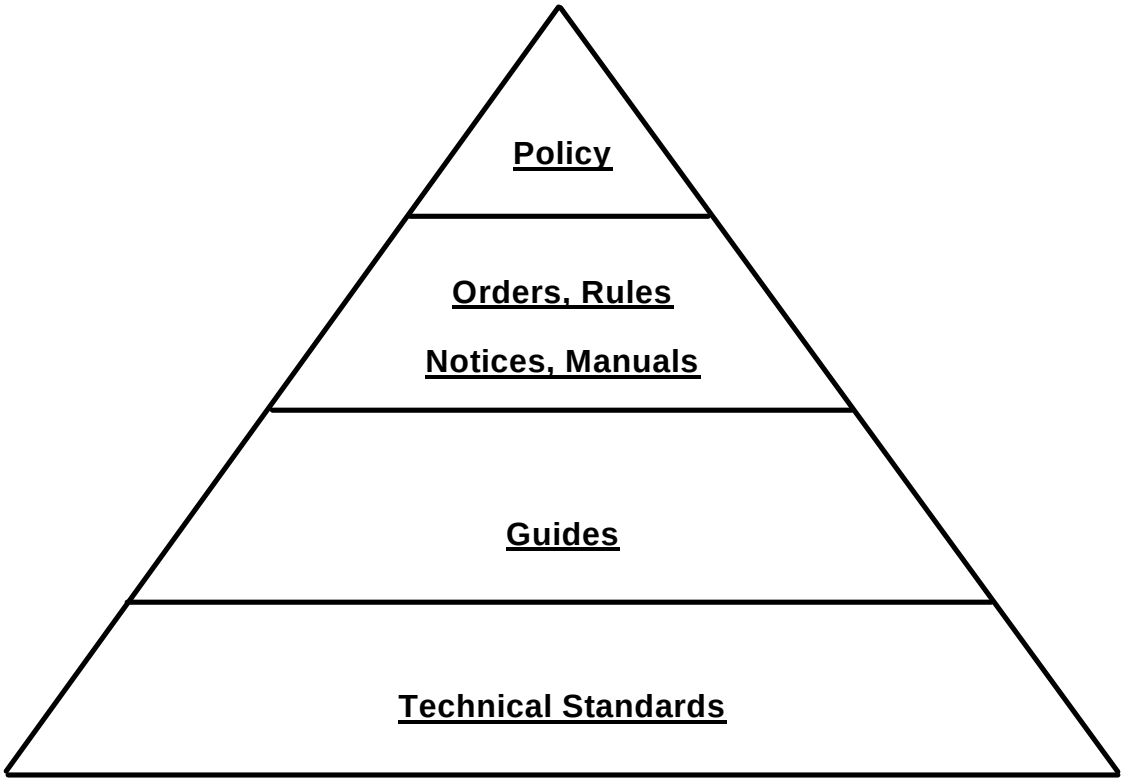
DOE Standards - DOE standards are another type of non-mandatory guidance document. Developed by DOE and managed by the Technical Standards Program, DOE Standards provide acceptable methods for meeting requirements. Safety and Implementation Guides typically reference Standards. DOE Standards do not supersede Orders, they simply supplement and clarify. If a method, such as the “graded approach” contained in DOE-STD-1027, is prescribed in a Standard, a contractor may or may not follow it. If they choose not to, it is incumbent upon them to document why their method is equivalent. DOE-STD-1027, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports is an example of a DOE Standard.

DOE Specifications - This term is not discussed in the DOE Order 251.1, Directives Systems of 10/16/95 or DOE M 251.1-1, Directives System Manual of 12/12/95.

DOE Handbooks - DOE Handbooks provide a source of information on various subjects, however they do not contain any requirements or guidance. An example of a DOE Handbook is any of the books in the “DOE Fundamentals Handbook” series which include topics such as: Nuclear Physics and Reactor Theory; Thermodynamics, Heat Transfer and Fluid Flow; Electrical Science; and Chemistry. Note: The term “DOE Handbook” is not discussed in the DOE Order 251.1, Directives Systems of 10/16/95 or DOE M 251.1-1, Directives System Manual of 12/12/95.

b. Describe the hierarchical system of documents used by the Department to establish its nuclear safety policy and the objectives, requirements, and guidance for implementation of that policy.

Attachment I-2 of DOE M 251.1-1, Directives System Manual, provides the best pictorial representation of the relationship between policies, orders, and standards:



As depicted, the system consists of four tiers. The top tier is "policy." Policy is the general philosophy promulgated from the Secretarial level (e.g. DOE P 410.1, Policy Statement on Developing Nuclear Safety Requirements). The second tier - Orders, Rules, Notices, and Manuals establish objectives and requirements to implement the policy (e.g. DOE N 441.1, Radiological Protection for DOE Activities). The third tier - Guides, provides supplemental information and clarification of the second tier documents (e.g. DOE G 471.2-1 Classified Matter Protection and Control Implementation Guide). The third tier is comprised of non-mandatory documents which establish acceptable ways to meet objectives and requirements. The fourth tier - Technical Standards, are additional non-mandatory documents which the higher tier documents may reference (e.g. DOE-STD-1027, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports). A lower tier cannot supersede a higher tier. All documents must be consistent with those in higher tiers.

References:

1. U.S. Department of Energy, *DOE-STD-1027, Hazard Categorization and Accident Analysis Techniques for Compliance with DOE Order 5480.23, Nuclear Safety Analysis Reports,* (Washington, DC: U.S. DOE, 1992).
2. U.S. Department of Energy, *DOE O 5480.23, Nuclear Safety Analysis Reports,* (Washington, DC: U.S. DOE, 1994).
3. U.S. Department of Energy, *DOE O 5480.22, Technical Safety Requirements,* (Washington, DC: U.S. DOE, 1992).
4. U.S. Department of Energy, *DOE O 5480.21, Unreviewed Safety Questions,* (Washington, DC: U.S. DOE, 1991).
5. U.S. Department of Energy, *DOE O 251.1, Directives System,* (Washington, DC: U.S. DOE, 1995).
6. U.S. Department of Energy, *DOE M 251.1-1, Directives System Manual,* (Washington, DC: U.S. DOE, 1995).